METALLURGIA

Making Super-quality Steels

A NEW HIGH-FREQUENCY FURNACE INSTALLATION

Many authorities on steel production assert that the high-frequency furnace will completely supersede the old crucible furnaces for the manufacture of high-quality steels. It is claimed that they can be operated in the manufacture of steel with laboratory precision, and, although of comparatively recent introduction, progress in their development has been rapid. The new installation at the Samuel Fox and Co., Ltd., works of the United Steel Companies, Ltd., which is the largest and most modern in Great Britain, is therefore of particular interest, and is briefly discussed in this article.

A general view of the high-frequency furnace intallation showing the 5-ton furnace being tipped, and the pits.

THE modern trend in manufacture is towards improved quality, and in no industry is there greater evidence of this than in the steel industry, particularly the high-grade steels, which must possess superior mechanical properties, greater reliability, and give increased service. The severe duties imposed by modern aeronautical and automobile engineering developments, the advent of high-pressure steam boilers and high-pressure high-temperature chemical plant, together with developments in practically every branch of engineering, have increased the demands of engineers for special steels of high quality. Specifications for these various grades of steel have become more and more exacting during the past few years ; they are expected to satisfy very severe tests, usually after forging and suitable heat-treatment, and as these operations are costly, it is becoming increasingly necessary to ensure that the quality of the steels used is of the highest order.

This trend towards higher quality primarily concerns the process of steel manufacture, and the increasing demand for special and alloy steels has directed attention to the need for an improved process capable of giving the maximum degree of control and yet producing on an economic basis.

With the advent of the electric-arc furnace it was confidently predicted that a solution had been found, but it became generally recognised that the intense heat developed by the arc presented several difficulties, and although this type of furnace has had a considerable influence on the crucible melting process, it has not by any means superseded this latter method for making high-quality steels. Later, low-frequency electric furnaces were introduced as a means of producing high-class steels in competition with the crucible and electric-arc furnaces.

The principle of heating by induction presents obvious advantages for melting steel without contact with contaminating influences, such as furnace gases or electrodes, but the older low-frequency furnaces had several drawbacks, chief of which were troubles with refractory materials, and the fact that these furnaces cannot melt from a cold charge. About seven years ago, however, a new type of furnace was developed, in which high-frequency electric current was used at a relatively high pressure. Although looked upon as a laboratory curiosity at that time, such rapid progress has since been made that to-day many authorities on steel production assert that furnaces of this

type will soon completely supersede the old crucible process which has held undisputed sway in the steel industry for about a hundred and fifty years. That the high-frequency furnace is destined to play an important part in the production of super-quality steels is indicated by the new plant installed at the Stocksbridge Works of Samuel

and install larger units still. The 2-ton and 5-ton furnaces which have now been installed are the outcome, therefore, of considerable experience in the operation of this type of plant. Opportunity has been taken of introducing many novel details of procedure and equipment, based upon this earlier operating experience.
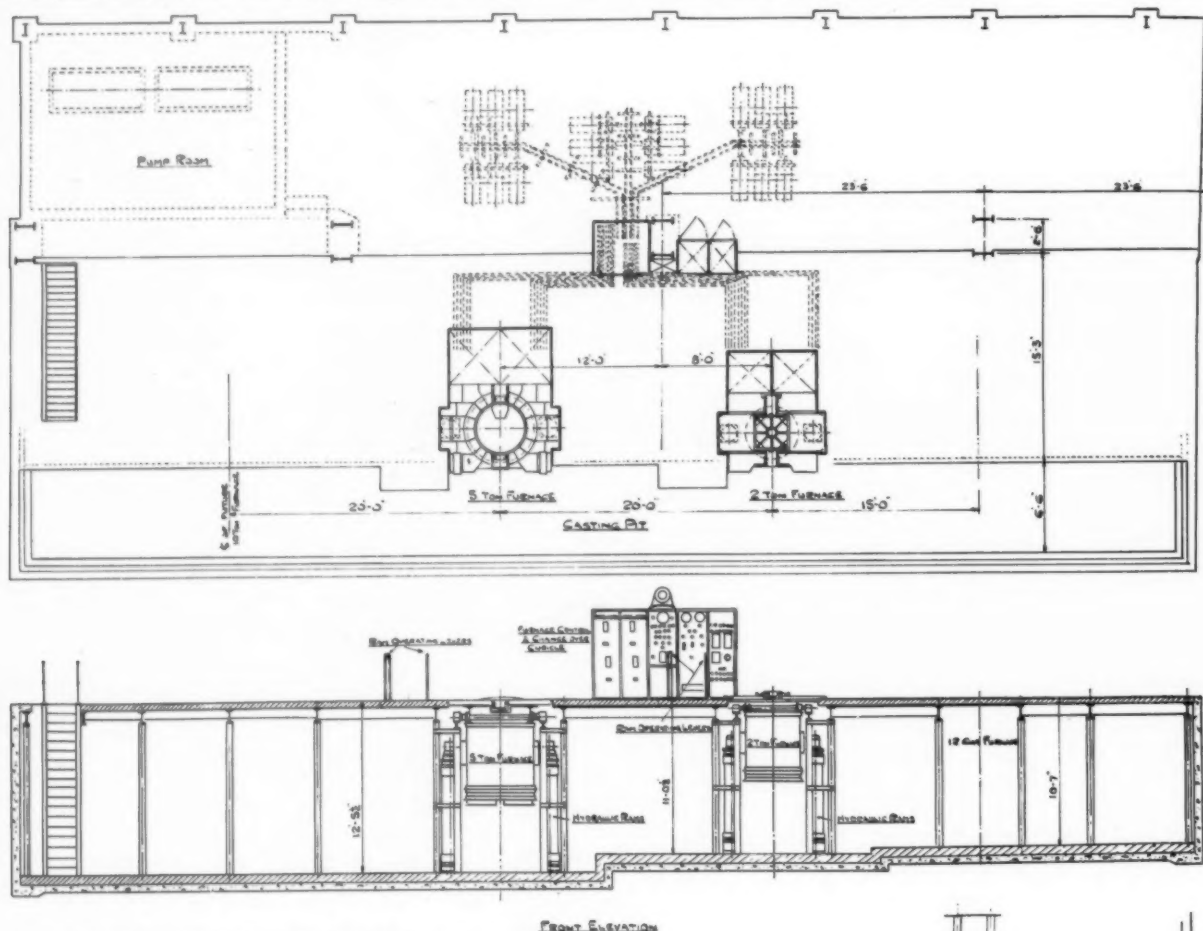
Plan and sectional elevations showing the arrangement of the furnace plant.

Fox and Co., Ltd., which is the largest high-frequency furnace installation in Great Britain.

Considerable research and experimental investigation has been directed to the perfection of high-frequency furnaces and, with the experience gained in their commercial application, results are now achieved in normal practice which, apart from demonstrating reliability, have given confirmation that they facilitate accurate control over the composition of the product, and therefore over the quality of the steel produced. During the comparatively short time this type of furnace has been introduced remarkable strides have been made. In the works of Samuel Fox and Co., Ltd., for instance, the first high-frequency furnace equipment comprised a small plant in the research laboratory capable of making ingots up to 20 lb. in weight. This furnace has proved invaluable in the production of small quantities of special steels for research purposes, the steel having all the characteristics of steel produced in larger units. In addition, this furnace has proved a most valuable asset for researches into slags, linings, and finishing alloys.

Some years ago a 5-cwt. high-frequency furnace was installed, and this was later followed by a second furnace of 12 cwt. capacity operated from the same generator. This initial plant so completely met the requirements for the production of high-class steel previously melted by the coke crucible process that it was determined to go forward
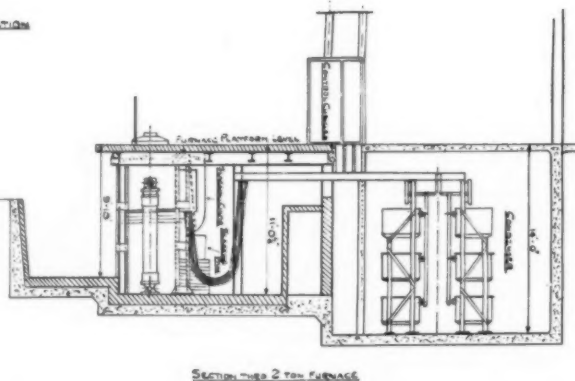
The value of the high-frequency furnace as a melting unit is now universally accepted. It provides a cleaner method of making steel. There is no contamination by carbon or sulphur. The analysis and temperature are under precise control, and there is a greater conservation of alloying elements than is the case in any other steel-making process ; moreover, these advantages are obtained at a cost that does not greatly exceed that of ordinary quality alloy and special steels produced in the open-hearth furnace.

Although the value of the high-frequency furnace as a melting unit is established, its usefulness for *refining* is only now becoming recognised. It has been proved, quite definitely, that carbon, manganese, silicon, sulphur, and phosphorus can be removed if desired. An even more

important aspect is that of " quality refining." This has particular reference to the control of the content of dissolved iron oxide, of dissolved gases, and of the factors which are controlled by accurate temperature control prior to casting.

In steel making refining reactions usually take place through the medium of a covering slag, and the speed of reaction depends upon the intimacy of contact between slag and metal. In the open-hearth and electric-arc furnaces the layer of slag covers the metal with (especially in the former case) comparatively poor facilities for intimate contact. In the high-frequency furnace, by virtue of a pronounced stirring action introduced into the molten metal, the essential contact is considerably facilitated.

which will enable the engineer to meet more and more exacting specifications, steels from this plant will find a waiting market.

The Furnace Equipment

The general impression of the melting shop strikes a new note in the appearance of steelworks, owing to the remarkable cleanliness under which steel is made, and the completely changed conditions under which the men work. The introduction of this electric furnace plant has done a great deal to ameliorate the life of steel melters, who are now able to work under conditions that are no worse than those in many mechanical shops. This ideal layout is due,

Tapping the 5-ton furnace.

A 5-ton cast of super-quality steel.

Experiments in slags have shown that suitable slags can be devised which permit of carrying out the desired refining reactions at the somewhat lower slag temperatures found in this type of furnace. This, in conjunction with the many other advantages which the high-frequency method of melting possesses, will enable the new plant to manufacture special and alloy steels of super quality, especially for highly stressed parts and heavy duties.

Amongst the varieties of steel which will be made in the new plant are steels for aircraft, racing and high-priced automobiles, and for specially severe duties in general engineering construction ; tool and die steels, especially for such arduous duties as plastics, dies, etc. ; automobile and aircraft valve steels, such as " Valmax " and " Suval " ; heat-resisting steels in the " Red Fox " series ; stainless steels in the " Silver Fox " series, where high-frequency electric steel will prove superior in freedom from surface and polishing defects ; " Nitralloy " steels for hardening by the nitrogen process ; highly alloyed steels for the electric industry (permanent magnet steels and non-magnetic steels) ; special welding rods, including very low carbon rods ; and very much improved steels for ball and roller bearings.

The ultimate deciding factor in the success of this plant will be the quality of steel produced. By " quality " is meant the regularity of analysis and mechanical properties, together with remarkable freedom from non-metallic inclusions and the reliability which goes with production in small carefully supervised units, and the manipulation of comparatively small ingots into the desired form. In short, wherever either by reason of a specially high content of alloying elements, or of specially arduous duties, or both these combined, there is a call for steel

of course, to the facility which is given in this new type of plant for large quantities of steel to be made economically with the precision of a laboratory experiment.

In addition to the high-frequency furnaces of 2 tons and 5 tons capacity, there is, in the same shop, a small open-hearth furnace of 15 tons capacity, capable, if necessary, of the rapid production of 5-ton charges of hot metal for the larger of the electric furnaces. There are several features about this furnace which are of interest, and may be mentioned briefly. It is a basic open-hearth furnace, the bottom being made up with magnesite and dolomite, but a siliceous insulation is formed as a protection ; it is one of the few furnaces of this type possessing a suspended roof, which, apart from fuel economy and evenness of heat distribution, has many other advantages. But probably the most interesting feature of this furnace is the control of operation. Change-over is operated on a temperature-difference principle which gives maximum efficiency, and the operating panel is so arranged that all information regarding the working of the furnace is available at once.

The induction furnaces are arranged for acid or basic lining, and tilt in both directions, so that slag can be removed from the back, and metal poured from the front of the furnace. The tilting mechanism is hydraulic, working entirely below the operating platform, and a wide range of tilting speeds is arranged to give flexibility of working. The furnace bodies are of heavy steel construction, and are provided with magnetic shields between the inductor coils and the furnace bodies. The control of the furnace is simplified by fully automatic gear, which controls the voltage, power, and power factor of the furnace throughout the complete melting period, the operator having only to set the controls to a predetermined value.
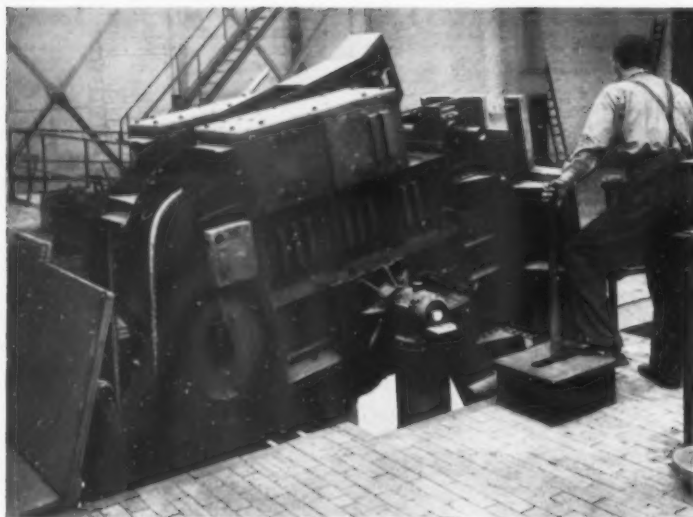
2-ton furnace in a tilted position, showing the hydraulic tilting rams and furnace leads.

Realising the importance of proper classification and storage of the differing qualities of raw material and alloys which are used, a separate building of over 3,000 ft. floor area has been provided for this purpose, served by an overhead crane, with railway siding and ample bunker accommodation.

The charges will be here weighed and prepared in special charge boxes, and transported by special bogies provided with suitable lifting apparatus, so that labour is reduced to a minimum. The material to be melted is then taken into the main melting shop, which consists of two main bays, 56 ft. and 62 ft. respectively in width, and 165 ft. in length, of which the larger bay is used for the electric furnaces.

The furnace-charging arrangements represent a great advance on previous practice, as the charges are prepared in an "Efco" charging cylinder let into the furnace platform for ease of handling. The overhead crane lifts the cylinder containing 2 tons of metal, and this is lowered into the furnace, the whole operation taking less than 2 mins. The great saving of time effected by this method is exemplified by the remarkably short time between furnace operations. During a full day's test run recently made, the average time between switching-off the current for casting and commencing the next melting operation was only 6 mins. During this time the furnace is cast into the ladle, cleaned, prepared, charged, and put to work again. This feature of the plant represents a very great advance, and is one of the characteristic advantages of this type of furnace, for the charging of other types of small melting furnaces requires at least 20 to 30 mins.

Arrangement of Melting Shop

The arrangement of the shop is very convenient ; the furnace bodies are flush with the working platform, so that there is no obstruction on the working level other than the electric control cubicles for controlling the furnace tilting gear and the water supply. The shop is laid out so that the working platform is at a convenient height for cleaning the furnaces from the general level of the shop, and ample casting pits are provided, so that casting operations can be carried out safely and efficiently. On the furnace platform excellent accommodation in the form of offices and laboratory are provided for the shop manager and chemists.

Electrical Equipment

The electric motor-generator set is housed in a separate building about 80 ft. from the furnace, an improvement upon the older methods of installation, where the machine

room was frequently placed in the melting shop, where conditions were not of the most favourable. The building, walls, etc., are tiled and equipped in the manner best for the maintenance of cleanliness. The condenser plant is housed in a sub-station under the working platform, where there are also circulating water pumps and ventilating fans.

The chief electrical machinery on this equipment consists of the main motor-generator set and associated switchgear and starting gear. The generator is a special type of inductor homopolar single-phase high-frequency machine of a novel patented design developed last year by the Metropolitan-Vickers Co. The alternator actually consists of two 625 k.w. stators with a common rotor, built in the form of one machine, enabling a total output of 1,250 k.w. to be obtained. Each stator consists of two separate halves and special arrangements are incorporated to prevent interaction between the magnetic circuit of one stator and the excitation winding of the other stator. The voltage of each of the two circuits can therefore be independently controlled and applied to two separate furnaces, operati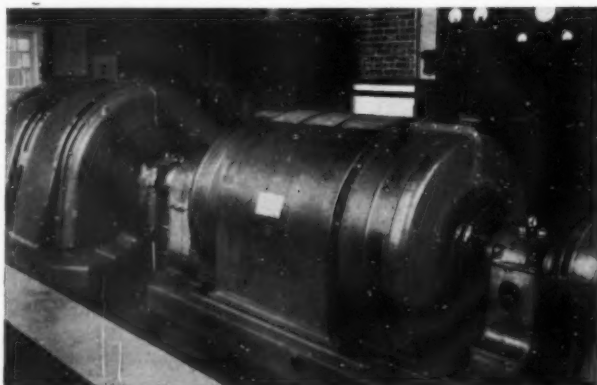ng at the same time. The full load voltage of each stator winding is 1,500 v., and when desired, both stators can be connected in series, with their excitation windings also in series, thus giving a single 1,250 k.w. supply at 3,000 v.

The driving motor takes its supply at approximately 11,000 v. from the 3-phase 50-cycle works mains, and apart from driving the high-frequency generator it is capable of taking a heavy leading k.v.a. from the mains in order to correct the general system power factor. The motor-generator set runs at 1,500 r.p.m., and is tap-started from an auto-transformer.

The high-frequency control scheme normally operates the furnace equipment under fully automatic conditions, and this is acknowledged to be a valuable feature. The furnace operator is thus relieved of all responsibility electrically, and is able to give his whole time to metallurgical work. Provision is also made to enable the equipment to operate semi-automatically or, if required, completely by hand-control. With fully automatic control the k.w. output from the high-frequency generator is maintained substantially constant at any value set by the furnace operator, and the generator power factor is also kept reasonably near to unity. As is well known, the power factor of a high-frequency furnace is very low indeed, and at the same time fluctuates considerably. The circuit is tuned by means of a large bank of condensers, and the capacity of the bank is varied automatically.

The automatic control of both high-frequency power and high-frequency power factor, as mentioned above, is carried out by means of robust but extremely sensitive instruments, which have been developed for this work.

The electric motor-generator set.

METALLURGIA

The British Journal of Metals

PRINCIPAL CONTENTS IN THIS ISSUE:

The Budget and Industry.

THE progressive spirit which continues to permeate British trade and industry, in spite of the enormous difficulties of the last few years, is faithfully reflected in the gradual increase being effected in production. The unemployment figures for March, while not entirely satisfactory, are a welcome indication that the steady upward movement, registered during the major part of last year, is being maintained. Industry shows some improvement everywhere, but in some districts, notably in the North-East area, the extent is very small. Recovery is definitely in progress, however, particularly when the employment figures are taken as an index, for these show that about 700,000 more are employed than a year ago. Engineering, the iron and steel industry, the motor industries, building, and the shipping service are among those which show an upward tendency. The fact that more people are employed means that more are earning and creating an increase of demand in the home market for goods, whether produced at home or imported from Empire or foreign sources. This upward trend is, therefore, progressive, since the increase of demand necessitates increased employment to satisfy the increasing need. It is a natural cumulative process and is very gratifying, but while trade is undoubtedly better, it is still bad, for we should not overlook the fact that over 2,000,000 are still unemployed. Britain is not alone in having these large numbers of unemployed ; this, however, does not mitigate the seriousness of the position, which constitutes an economic and moral problem of the gravest dimensions, and continues to challenge the British Government as well as the governments of almost every civilised country.

A direct indication of improved trade is the welcome information that revenue receipts exceed expenditure by over £50,000,000, and the allocation of this surplus, which gives Mr. Chamberlain the opportunity of presenting the brightest Budget for many years past, should do much to assist industrial recovery and incidentally to ameliorate in some measure the suffering and decay resulting from unemployment. With so much at his disposal, the Chancellor should be able to avoid the multiplicity of disappointments to which a Chancellor is normally constrained. Budget surpluses have been so rare in recent years and the prospect of reduced taxes and higher expenditure is so cheerful that there has been much controversy over the disposal of the surplus ; in one direction only is opinion fairly general, and that is in regard to the restoration of cuts in the unemployment benefit payments made in 1931. Most people have an instinctive sympathy with this suggestion, and we confidently expect that the restoration will not be confined to raising the allowance for dependent children, but to the larger question of unemployment payments as a whole. This is a question of equity rather than of economics, and should be considered as an act of social justice. With such a surplus the Chancellor can assuage the sharpest of the crisis cuts, reduce the call for income-tax, and still have a considerable amount for distribution, and the disposal of the latter will indicate the Government's outlook and policy, and have a considerable influence on public opinion.

Releasing the surplus by relaxing individual economies will increase confidence in the immediate economic future, and will undoubtedly increase the amount of employment necessary to keep pace with the increasing demand. It is in this direction that—at least in part—a cure for unemployment lies, but action of a more spirited nature is necessary to have any substantial effect in removing this serious canker. The Government has shown proof of some initiative in attacking the problem by its action in facilitating the restarting of the Cunarder and in pressing forward a housing programme of no mean conception, but as yet these are only touching the fringe of the problem. Their cumulative effect, however, is bound to have a big influence in helping towards recovery.

Despite the difficulties that are still pressing heavily upon Britain, there is solid ground for satisfaction and hope for the future, but no reason for complacency. It is true that domestic expansion has been particularly marked in the main equipment trade, due largely to the reduction of imports of supplies as a result of the tariff, but while this progress is encouraging, there is a real danger that the level of even the domestic production may be seriously impaired by foreign competition in the form of depreciated currencies, subsidies, or through increasing competition from countries with a lower standard of living, whose conditions Britain neither can nor should emulate. It is necessary that the Government should develop a constructive policy which will preserve a reasonable competitive spirit in the home market, not so much to render negative these potential dangers, but to give British manufacturers a fair market for their goods.

It is in the export trade, however, that greater progress is necessary if Britain is to make any serious attack on the unemployed problem. In this direction it is true some progress has been made ; Great Britain has regained her position as the chief exporting country of the world. This does not mean that the value of her exports have reached what may be regarded as normal but that she has done better than her competitors in a world that has a greater desire to sell than to buy. Thus, although the chief exporting country, Great Britain is not yet selling that volume of goods which alone will enable her to reduce the number of her unemployed appreciably.

It is recognised that British manufacturers have made vast strides in the direction of efficiency of production, and can take credit for contributing towards the expansion of trade already experienced, and while there is much yet to be done in this direction, until normal trading conditions return the outlet for manufactures will be restricted. As Sir George Macdonogh stated, in his address at the annual meeting of the Federation of British Industries, the world still seems wedded to economic nationalism, as evidenced by high tariffs, quotas, subsidies, and exchange restrictions. No progress towards a freer flow of trade has been made by general international action. If there is to be any real revival of trade, it is imperative that Great Britain should resume her role as leader in the offensive against forces of contraction. In order to do so the Government should not flinch from using the powers which it now possesses, or with which it could arm itself. It has every reason to be pleased with the opportunity to do much good with the Budget, but its energies should also be directed with increasing force and assurance to further trade expansion both at home and abroad, so that industry will be able to absorb labour at a greater rate.

IRON AND STEEL REORGANISATION SCHEME

DETAILS of the proposed constitution of the British Iron and Steel Federation have just been issued. The constitution provides machinery for the complete reorganisation of the industry which was undertaken at the urgent request of the Government when the $33\frac{1}{3}\%$ tariff on imported iron and steel was imposed. This duty expires in October next, and the reorganisation is a condition of its renewal. The first draft scheme presented by the Federation's committee, which took nearly a year to prepare, was rejected by the Federation. A few months more were occupied in framing the shadowy scheme which has been accepted in principle and in general terms by the members of the Federation. Another committee was appointed to give effect to amendments and take into consideration suggestions. The scheme, with such modifications as were considered necessary at the last meeting, will be considered at a meeting to be held on April 19.

As was to be expected, there has been considerable controversy regarding the proposed scheme, and about a couple of months ago the Imports Advisory Committee found it necessary to intimate that unless the new scheme was accepted and set working its present " Protection " might be withdrawn from the industry. The committee further hinted that it expected real reorganisation as well as the faint imitation of it which is all this scheme assures. When all the objections of the members are pruned, will there be anything of real value left for the members to agree upon on April 19 ? Fortunately, the Imports Committee and the Government can bring pressure to bear upon the attitude of the Federation to ensure a degree or reorganisation capable of bringing about economy in production that can be passed on to the various trades which depend upon cheap steel.

The scope of the scheme embraces the need of concentrating and perfecting production and of reorganised marketing, and in view of the remarkable increase in the production of British iron and steel since the tariffs on imported products were imposed, every effort should be made to pass on the benefits which have accrued to facilitate progress in other trades, particularly those that are in keen competition with other countries in world markets.

According to the new constitution of the Federation, the scope of the scheme is extended, and provides for facilities for ascertaining the views of persons engaged in carrying on the industry in Great Britain, Northern Ireland, the Dominions and Dependencies, and the Indian Empire. The communication and interchange of views between members of the Federation and between the Federation and the Governments and Government Departments of the United Kingdom, British Dominions and Dependencies and Indian Empire, and of foreign countries and any other allied trades authorities, organisations, and persons, whether in the United Kingdom or elsewhere, on all matters directly or indirectly affecting the industry. The Federation will arrange with governments, whether British or foreign, other industries, etc., in regard to any action which may be proposed by them or desired by the Federation. It will promote, support, oppose, or influence legislation and other matter affecting the industry or allied trades ; provide services of an advisory character, such as statistics and trade intelligence ; promote and foster the formation of associations in the industry within Great Britain, with a view to their affiliation to the Federation ; provide suitable means for adjusting matters in dispute within the industry by arbitration ; and will organise and regulate, in consultation with the affiliated associations concerned, the control and disposal of imports of iron and steel products. The Federation is to act on the governing principle of the complete autonomy of each affiliated association. Several committees are proposed which will include a Parliamentary Committee, Transport Committee, Tariff Committee, and Research Committee. A Council consisting of 29 persons engaged in the industry is proposed, and these are to be elected annually by the Federation's members. ·

This constitution will be discussed at the meeting on April 19, and it is expected to be accepted, but whether it will ensure the fulfilment of the main object—concentrating and perfecting production and reorganising marketing— remains to be seen. In the first place, however, it is hoped to gain the approval of the Import Duties Advisory Committee.

AN EMINENT METALLURGIST

DEATH has taken one of the world's most distinguished metallurgists, Dr. Walter Rosenhain, F.R.S. Educated in Melbourne, Australia, he graduated in 1897 from the University of Melbourne in Physics and Engineering. He then came to England as holder of one of the Research Scholarships of the Royal Commission for the Exhibition of 1851, which enabled him to spend three years at Cambridge, where he worked mainly in collaboration with Professor (now Sir Alfred) Ewing. It was at the suggestion of the latter that he took up the microscopic examination of metals, having first spent some time with the late Sir William Roberts-Austen at the Royal Mint, and with the late Professor J. C. Arnold at Sheffield, in acquiring the technique of the new work. This work shortly lead to the discovery of " slip bands " and, a little later, to that of the phenomenon of spontaneous annealing or recrystallisation in lead and other soft metals at room temperature. His most important work, however, was during his connection with the National Physical Laboratory, which dated from 1908, when he was appointed first Superintendent of the Department of Metallurgy and Metallurgical Chemistry, a post which he held for 23 years. The Department, newly formed in 1906, was very small with a total staff of only four ; it has grown immensely in size and importance since that time and is now regarded as one of the foremost research laboratories in the world. Dr. Rosenhain himself published a very large number of papers and addresses, but under his leadership a still larger number of contributions to scientific metallurgy have been made by the staff of his Department at the National Physical Laboratory, this work covering the whole field of physical metallurgy, both ferrous and non-ferrous.

Dr. Rosenhain was elected Fellow of the Royal Society in 1913. He was President of the Institute of Metals from 1928 to 1930, and was elected a Fellow of that Institute for his eminent services to that society. He was also a Fellow of the Institute of Physics and a Member of the Iron and Steel Institute, and numerous other scientific and technical societies. Since 1927 he was British Delegate on the Permanent Committee of the International Association for Testing Materials and was appointed President of the Association at the Zurich Congress held in 1931. He was invited at different times to give lectures and addresses in many countries (America, 1923 ; Germany, at Düsseldorf, 1929 ; Switzerland, at Zürich, 1929 ; Sweden, at Stockholm, where he gave an opening address at the meeting of the Jernkontoret in Stockholm), and he delivered the 1923 May Lecture before the Institute of Metals on " The Inner Structure of Alloys."

Dr. Rosenhain resigned his position as Superintendent of the Department of Metallurgy and Metallurgical Chemistry at the National Physical Laboratory at the end of May, 1931, in order to take up private practice in London as a consulting metallurgist. In that capacity he was connected with the British Aluminium Co., Ltd., the Broughton Copper Co., Ltd., and Messrs. J. Stone & Co., Ltd.

He had a charming personality, was always interested in the advancement of metallurgical science through various institutes, and could be relied upon to initiate discussion. The younger metallurgists in particular will miss his ever ready assistance and advice on any subject relating to metallurgy. Britain can ill afford to lose such men of genius, and we join with many at home and abroad in expressing our sincere regret that he should have been taken at the comparatively early age of 58.

Air-cooled Combustion Chamber Walls

Two types of suspended furnace wall construction are discussed. Both are designed on the composite principle, with a separate but interlocking inner and outer lining.

I T is well known that the ordinary solid wall is now obsolete for many types of metallurgical furnace, especially for high duty conditions, following upon the example of the water-tube boiler. As a result of the extensive experience that has been obtained in this field, a number of different types of suspended wall is now available, and in this connection considerable interest attaches to the latest designs of the Bigelow "Type D" and also the "Type DX" suspended wall, which are productions of Liptak Furnace Arches Ltd., of London (59, Palace Street, Victoria Street, S.W. 1.). A complete range of different designs of suspended walls and arches is available, designed to ensure that the best results are given under any conditions, such as, for example, the size of the settings, the rate of combustion, and the percentage and melting point of the ash when coal is used.

As is well known, the standard "Bigelow" suspended wall in general principle consists essentially of three components only, cast-iron carriers, high-grade fireclay blocks, and standard firebricks, using a steel framework. To the latter is bolted a series of cast-iron brackets with a flanged portion, the fireclay blocks having an indentation or groove at the top so that they hang suspended from the castings. Each individual block is quite independent of any other block, being easily replaced without affecting the rest of the wall, all troubles due to expansion and strains due to weight of a mass of wall being eliminated.

This standard suspended wall with air cooling between the back of the wall and an outer casing is quite satisfactory for ordinary conditions, but for more severe duty the "Type D" wall is supplied, which is on the composite principle, having a separate but interlocking inner and outer fireclay block or lining, each of which is narrower, so that the overall thickness of the composite wall is only about 11½ in., the same as the standard wall. That is, the inner lining, something on the same lines as the "Liptak" suspended arch, is suspended to the outer lining, which latter is itself suspended from steel girders, the construction also of the two linings being on the staggered principle to ensure tightness both as regards air and gas leakage.

This arrangement also allows of cheaper fireclay blocks being used for the outer lining and higher-grade material for the inner lining, which means that any repairs to the wall can be carried out more economically, since of course it is only the inner lining that is affected.

In the "Type DX" wall the blocks of the inner lining are made of special high resistant silicon carbide instead of fireclay, which is particularly useful for furnace walls in the slagging zone of a combustion chamber. In general also a composite wall of this kind combines the inherent advantages of both fireclay and silicon carbide, while the part of the wall above the slagging zone can be constructed on the "Type D" composite principle, or on the lines of the ordinary standard non-composite wall.

In addition both these types of composite wall are well suited for operation in conjunction with the "Liptak"
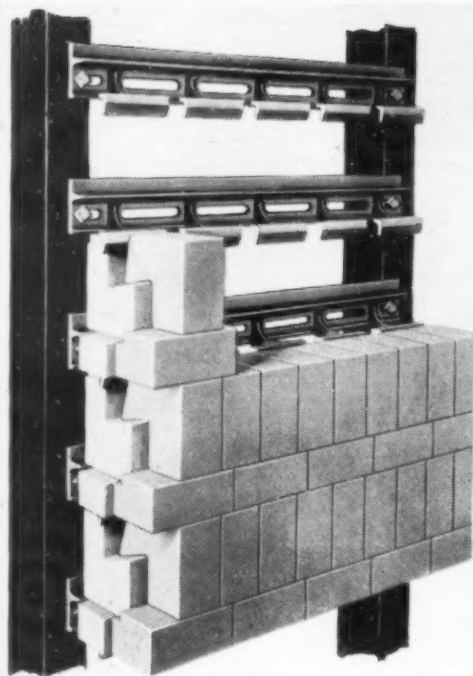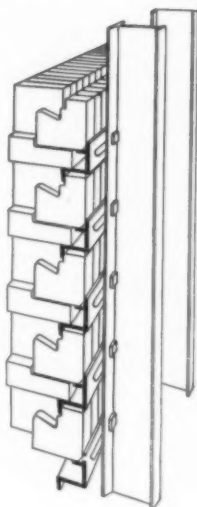
Suspended " D "-type walls for combustion chambers, showing the inner and outer layers of interlocking blocks of equal width, and also the method of constructing the wall.

double suspension flat arch, having as already indicated a double row of interlocking fireclay blocks, one attached to the other, the whole being suspended from steel girders forming a flat arch or roof, particularly suited for many types of metallurgical furnace.

Reducing Intergranular Corrosion in Chromium-Nickel Stainless Steels.

Investigations carried out by Russell Franks and Dr. F. M. Becket, the results of which were presented at the recent annual meeting of the American Institute of Mining and Metallurgical Engineers in New York, indicate that the addition of columbium in moderate and economical proportions prevents intergranular deterioration of austenitic chromium-nickel steels when exposed to elevated temperatures and chemical corrosion. This improvement in resistance to corrosion is claimed to be effected without sacrifice of present valuable properties of these steels.

In these investigations it was observed that the presence of columbium in the ratio of about four to one of carbon diminished the range of temperatures through which these steels were attacked at grain boundaries. When the ratio of columbium to carbon was increased to about seven to one, a marked improvement was shown, although disintegration was still possible. Further increases of columbium to a ratio of ten to one gave steels that failed to disintegrate after exposure to long or short periods at all temperatures between 300 and 850° C. Except with very low carbon content, columbium does not correct greatly the loss of toughness characteristic of exposure in the approximate range of 650-900° C.

Increasing demand for their new Kanthal Alloys as elements for electric domestic appliances, electric furnaces, etc., has led to the publication of a further and more complete brochure by Messrs. Hall and Pickles, Ltd., of Manchester, which gives information and valuable data regarding these alloys. It is claimed that these alloys ensure a long life, with great economy, and are capable of resisting temperatures up to 1,350° C., with high specific resistance and resistance to oxidation, while they are also claimed to have greater resistance to the attacks of sulphur than nickel-chromium alloys used for similar purposes.

ALLOY STEELS IN INDUSTRY
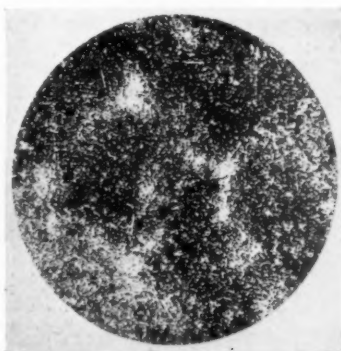
By Professor Sir Henry Carpenter, D.Sc., F.R.S.

The development of alloy steels has had a profound influence on industry in general, and on engineering in particular. The evident marvels of modern engineering are expressions of less evident materials which are the marvels af metallurgy. In this article the author gives a brief historical survey of the field embraced by alloy steels and discusses some of their characteristics.

AN alloy steel may be defined as one which contains one or more elements other than carbon, purposely added to modify and improve substantially one or more of its useful properties. The qualification "in sufficient proportions " must be included, because elements may be added to straight carbon steels for other reasons— *e.g.*, to give the desired composition and to prevent the occurrence of some defect to which the final product might otherwise be liable. Manganese is present in all ordinary steels made by any of the large-scale processes, and it is necessary to have it, otherwise the steel is red short. For this purpose the amount required does not exceed 1.5%. The product, however, is not an alloy steel but remains a straight carbon steel. The well-known "manganese steel " contains a relatively large amount, usually from 11 to 14%, of this element which is needed to produce the characteristic and, up to the time of its discovery, novel properties of this type of steel. This is a true alloy steel. Something
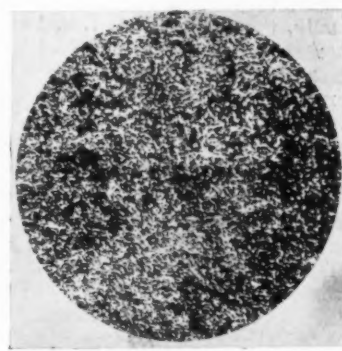
before iron in the system, and thus have the three immediately preceding atomic numbers—viz., 23, 24, and 25—that of iron being 26. Cobalt and nickel, which follow, have the immediately succeeding atomic figures, 27 and 28. *Five out of the seven metals, therefore, are the immediate companions of iron.* The remaining two, molybdenum and tungsten, are homologues of chromium. All of them are high melting metals. Iron melts at about 1530° C., and, with the exception of manganese, the remaining metals all melt above 1450°, while two of them, molybdenum and tungsten, are among the highest melting metals known. Their crystal symmetry, with the possible exception of manganese, is also closely allied to that of iron. Each of them crystallises in the cubic system, four of them in precisely the same subdivision as iron—viz., the body-centred cube—while the remaining two crystallise in the face-centred cube. The capacity to form alloy steels has thus been found to be confined to a small number of metals
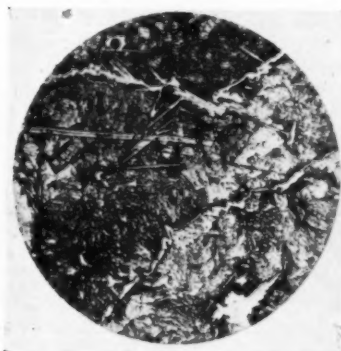
Structure as cast × 300.   After heat-treatment × 55.   After heat-treatment × 300.

The structure of a complex alloy steel containing iron, carbon, manganese, nickel, chromium, and molybdenum, made for withstanding heavy duty in service, as in the case of Pilger rolls. (W. F. Rowden.)

like 30 years elapsed between the patenting of the first alloy steel and the period during which they have become well-established industrial materials. Since then, however, their influence on engineering practice in all its varieties has been quite remarkable, and it is no exaggeration to say that they have revolutionised the technique of its procedure.

Elements Employed.

It is somewhat remarkable to find that in spite of the large number of metals available, comparatively few have proved themselves suitable for the manufacture of alloy steels. It is not suggested that finality has been reached in this respect, and there is little doubt that, with the progress of investigations, a greater number of metals will be used in the course of time. It is, however, significant that by far the greater number of alloy steels which have found industrial applications are composed of one or more of only seven alloy metals. These are, in the order of their atomic weights and numbers, vanadium, chromium, manganese, cobalt, nickel, molybdenum, and tungsten. All of them are Group A metals in the periodic system, with the exception of cobalt and nickel, which occur in the same group as iron itself. The first three occur just

adjacent to iron in the periodic system which are high melting and possess a very similar degree of crystal symmetry. These properties undoubtedly make for good miscibility of the metals in question with iron. One other element, silicon, a non-metal and chemical homologue of carbon, forms steels which are generally classified as alloy steels.

The simplest possible alloy steel is a ternary steel. It contains three elements—iron, carbon, and the alloying element in question. Tungsten, chromium, manganese, and nickel steels fall into this class. In many cases, however, two alloying elements are present and in this case the steel is known as a quaternary steel. Well-known steels of this type are the nickel-chromium, chromium-vanadium, chromium-tungsten, and silico-manganese steels. There still remain, however, a number of steels which are even more complex, and contain three or four or even five alloying metals. These are generally classified under the head of complex steels. Examples of these are found among high-speed cutting tools, which may contain chromium, tungsten, vanadium, cobalt, and molybdenum, and heat-resisting steels which may contain chromium, nickel, tungsten, and silicon.

The First Alloy Steel.

So far as I am able to ascertain the first useful alloy steel made was Mushet's self-hardening tungsten tool steel, patented in 1868. Tools have always been and still remain the most important metallic products. Prior to Mushet's patent, the most efficient tool was made by quenching a carbon steel in water from above 750° C. Provided the chilling was properly carried out, the hardness of the steel could be increased about six times by this process. It is obvious that it depends for its success upon the capacity to withdraw heat from the steel at a sufficiently rapid rate. There is no difficulty about doing this for thin sections—e.g., knives and tools of moderate size can be properly hardened in this way. It is, however, not possible to withdraw heat sufficiently rapidly at 750° C. from a thick mass of steel to enable it to be hardened, and therefore the hardening of such a mass cannot be accomplished by quenching. It can, however, be effected in another way—viz., by a change in composition produced by adding an alloying element—nearly always a metal. This was Mushet's discovery. As the name indicates, his steel did not require water quenching to enable it to be hardened. In virtue of the tungsten and manganese which it contained, it became hardened by merely cooling in air. This was the first case of deliberate hardening of steel simply by a change in the composition, and Mushet was the first man to prepare a steel-cutting tool which did not require quenching in a liquid. His air-hardened steel is generally considered to be a tungsten steel. It contained, indeed, 6% of this metal, but it also contained about 2% of manganese and 2% of carbon, and the manganese was required to give the steel the self-hardening property ; actually, therefore, it was a quaternary steel. It had a remarkable career of usefulness and formed an indispensable link in the development of high-speed tools, which will be referred to presently. For some time it has been practically obsolete.

Tungsten Magnet Steels.

Plain tungsten steels, however, have another use, in virtue of the magnetic qualities which they can be made to possess. They find application in permanent magnets for electric motors, in small dynamos, and for hand use, and by far the greater part of the annual production consists of a steel containing about 6% of tungsten and from 0.6 to 0.75% of carbon. To obtain the best magnetic qualities such a steel must be heat-treated, and, therefore, all magnet steels are used in this condition. The process involves two operations : (1) The steels are hardened by heating and quenching, and (2) they are then magnetised, and if they are to be used for electric motors they are " seasoned " by a protracted heating at 100° C., so as to make their magnetism as nearly constant as possible. At the present time a great variety of alloy magnet steels is manufactured. The majority of these contain chromium as an essential constituent and either tungsten or cobalt or both. It must be confessed that we are completely ignorant of how these alloying metals act in improving the magnetic qualities of carbon steels. The compositions quoted have been arrived at empirically by experiment. The explanation of their action must await proper scientific investigation.

Ternary Chromium Steels.

Plain chromium steels were some of the earliest alloy steels to be made. They were used for a variety of purposes, in all of which, however, the property of hardness was an important factor. These uses date from about the year 1880. The earliest application of such steels, which is still current, is for stamp shoes and dies for crushing gold and silver ores. These contain from 0.8 to 0.9% of carbon and from 0.4 to 0.5% of chromium. Toughness as well as hardness is an essential property of these steels, and some annealing is always required in their heat-treatment. Another important use is in the form of 5-ply plates for the manufacture of safes. Hardened chromium steel rolls are used for cold rolling metals. These contain 2% of

chromium, 0.9% of carbon, and are glass-hard. Another important use is in the manufacture of files. Balls and rollers for bearings are generally made of such steels, containing about 1.1% of carbon and 1.4% of chromium. All sizes smaller than 0.5 in. in diameter are water-quenched from about 770° C., and then tempered at 190° C. for 30 mins. Larger balls are quenched from about 800° C. By means of the tempering treatment the balls are toughened, internal stresses are lessened, and there is less liability to crack. Mr. Hibbard[1] states : " The strength of a good, well-treated ball is prodigious." A ball, ¾ in. diameter, tested by the three-ball method, sustained a load of 52,000 lb. On the small area of contact the intensity of the pressure amounted to over 1,000,000 lb. per sq. in. It will be observed that in all these uses the quality of hardness is the outstanding property required.

Rustless Steels.

It is very remarkable that an entirely new use for chromium steels was discovered more than 30 years later, particularly as the literature of the intervening period contains many references to the preparation and properties of chromium steels. Mention may be made of the extensive researches of Sir Robert Hadfield, in this country, and Messrs. Guillet and Portevin, in France, but none of these investigators, nor any others up to 1913, discovered that high chromium steels when suitably heat-treated were remarkably resistant to corrosion. This particular discovery was made by Mr. H. Brearley, in 1913. So rapid and important have been the manufacturing developments that followed on his discovery that the corrosion and stain-resisting properties of heat-treated chromium steels now constitute a very important application of this alloy.

Mr. Brearley's discovery of the corrosion-resisting properties of chromium steels was unpremeditated. He was engaged at the time in a research on the resistance to erosion of various steels for ordnance purposes. Among the steels examined were some containing large amounts of chromium in different conditions of heat-treatment. It was noticed that the high chromium steels were often not etched at all or could only be slightly attacked by the usual agents employed in the microscopic examination of steel sections and, moreover, that they did not rust in the atmosphere of the physical laboratory. Mr. Brearley's patent stated : " A typical composition for the untarnishable steel embodied in my invention would be as follows :—carbon, 0.24% ; manganese, 0.30% ; chromium, 13.0% ; iron, 86.46%. In producing such metal embodied in my invention I preferably use an electric-arc melting furnace. It can be readily made in such a furnace. It forges easily into sheets or strips, such as are required for knife blades, for example, and can be hardened and tempered by ordinary commercial process." It is made clear in the patent specification that if this steel is to be resistant to corrosion it must not contain any microscopically distinguishable free carbides. Its corrosion-resisting properties, therefore, are dependent upon the whole of the carbon being dissolved.

Stainless Steels.

Not all stainless steels are plain chromium steels—some of the most important of them contain nickel as well, but all of them without exception contain chromium in considerable amounts, and the essential corrosion-resisting properties are due to this metal. The discovery of stainless steel is one of the major inventions of this century, and the great variety of its applications is only now beginning to be realised. The range of properties which can be obtained is such that it is no longer correct to regard stainless steel as a particular kind of steel, but rather as a modified form of it, in which most of the mechanical properties of ordinary steels may be obtained in addition to high resistance to corrosion.

Recent progress in the manufacture of corrosion-resisting

[1] H. D. Hibbard, " Manufacture and Uses of Alloy Steels," J. Wiley, Inc., New York, 1919.

alloys has depended on the use of nickel in addition to chromium, as by this means it has been possible to extend the range of resistance to corrosive conditions. The alloy manufactured in England under the name of " Staybrite " contains 18% of chromium and from 8-9% of nickel. Other varieties of this type are " Anka " and " V2A." Unlike ordinary stainless steel, which is a two-phase alloy, and has to be heat-treated in order to provide optimum resistance to corrosion, these alloys in the natural state consist of a single phase, the iron being in the austenitic condition. The alloys are ductile and can be worked into almost any form. Staybrite can also be welded, but it cannot be hardened by quenching, although a certain amount of hardening can be produced by cold work.

High-speed Steels.

The year 1900 witnessed a remarkable discovery by Taylor and White, in the U.S.A., in respect of alloy steels containing tungsten and chromium, which produced a revolution in workshop machining practice. The Mushet self-hardening tool was a tungsten-manganese steel. If the percentages of carbon and manganese are considerably reduced, and chromium, with or without vanadium, is added, the resulting alloy is also a tool steel, but it possesses even more remarkable properties than Mushet steel. This was the Taylor-White discovery. They found that when such steels were subjected to a particular heat-treatment the resulting tools possessed properties entirely different from those of a carbon steel or Mushet tool. The heat-treatment required departed from all previous practice and, indeed, violated all the best accepted canons of such treatment. Whereas great care has to be taken not to overheat a carbon steel tool and, to a rather less extent a Mushet tool, in hardening, the tungsten-chromium tool steels introduced by Taylor and White required to be subjected to a heat-treatment in hardening so high that the " nose " of the tool was in a state of incipient fusion. These tools then required a second heat-treatment also at a much higher temperature than a carbon-steel tool— viz., from 550° to 600° C. After this they were in a condition to work and actually did work at temperatures far above those which would destroy the cutting power of any previously used tool. Not only did the new tool machine the work at a red heat—as a result of which they were said to possess the property of red hardness—but they did not exhibit the best cutting properties unless they were used at these high temperatures. On account of this property a tool made of such high-speed steel could be made to cut continuously at speeds from three to five times as great as that practicable with other tools, and when, as a result of the friction of the chip on the tool, the temperature may be 700° C. at the point of contact, and the chip itself heated to about 300° C. As a consequence of this the chips machined from the work in this way are tempered a deep blue on the surface.

The Taylor-White process, as worked out at the Bethlehem Steel Company, was not a chance discovery. It was the final result of many experiments and years of hard work by Taylor, an engineer, and White, a metallurgist. The full story is told by Taylor in his presidential address to the American Society of Mechanical Engineers, 1906. Since the original patents were issued in 1901 others have been granted for almost every possible combination of elements which were in any way thought to be useful or valuable constituents of tool steel. Improvements in detail have been effected, but the Taylor-White process, which consisted partly of a new composition, and partly, and even more importantly, of a new heat-treatment, remains essentially unaltered to-day. These steels have in the past quarter of a century worked an entire revolution in the machine-shop practice of the world, permitting largely increased outputs and commensurately lower costs. Their position in recent years, however, has been challenged by the use of tools composed essentially of certain hard carbides—e.g., tungsten carbide. These constitute even

harder cutting materials, and are rapidly being incorporated in present-day practice.

Manganese Steel.

Returning now to the early 'eighties, mention must be made of one of the most remarkable alloy steels ever made—viz., the so-called manganese steel. The metal manganese occupies a position of peculiar importance in steel metallurgy. It is required in the manufacture of all ordinary steels and, in spite of a large amount of investigation, no satisfactory substitute has yet been found for it. Very large quantities are, therefore, used annually for this purpose. It is also the essential constituent of manganese steel. This alloy in the commercial meaning of the name is a variety of steel containing from 1.0 to 1.3% of carbon and from 11 to 14% of manganese. The original patents covered steels with from 7 to 30% of this metal, but alloys within the limits of the composition given have the greatest strength and ductility, and are, therefore, generally used. The discovery of this steel and the working out of its properties over a period of many years will always be associated with the name of Sir Robert Hadfield. It undoubtedly is one of the most important alloy steels ever discovered and certainly it has become one of the most famous. It was the pioneer of steels of a new type, and the economies resulting from its use in various fields of service have been remarkable. As Mr. Hibbard[2] has pointed out, " Perhaps the most conspicuous example of its use was in connection with the Panama Canal, where years of time and millions of expense were saved by its use." The bulk of the manganese steel made at the present time is in the form of castings, but the use of the hot-worked (rolled and/or forged) steel is now also of considerable importance.

In the untreated state the properties of manganese steel are similar to those of untreated high-carbon steels. The metal is very hard and its ductility is almost negligible. In order to develop the toughness which is so characteristic a property, special treatment is required. It consists in heating the article in question to 1050° C. and then quenching it as rapidly as possible in cold water. Special care is needed to ensure that this operation is successful. The steel is a poor conductor of heat—a fact which does not make its heat-treatment easy, and tends to limit the thickness of the steel that may be profitably treated, which is generally about 4 in. It also requires to be heated slowly. The hardness of the toughened steel is unique in that it was the first example obtained of an alloy steel which is both hard and tough. Hardness is tested by a variety of methods, each of which tests a particular aspect of this composite property. From these, somewhat varying conclusions can be drawn as to the hardness of manganese steel. It can easily be dented with a hammer and marked with a file or a chisel. Its Brinell ball hardness is not high. Its elastic limit is surprisingly low. None of these results would suggest that it was a particularly hard alloy. It can be cut only with the greatest difficulty, because of the transformation of the austenite into very hard martensite under the action of cold work ; this is the cause of the remarkable resistance to abrasion exhibited by this steel. It has to be ground to shape with an abrasive wheel. The water-toughening described gives it great ductility, particularly in respect of elongation, which is greater than that of almost any other steel, and sometimes exceeds 50% on 8 in. In spite of this its high degree of hardness is not greatly altered. Practically all manganese steel is used in the toughened state, and the combination of hardness with ductility thus achieved gives great resistance to abrasive wear as well as safety from breakage. The disadvantage of the steel is that it possesses the combination of low elastic limit and high ductility, as a result of which it is prone to flow under stress. It does not possess high resistance to compression or to continually repeated blows of hard mineral which will gradually batter it out

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2 H. D. Hibbard, loc. cit.

of shape, but probably no alloy steel has found so many uses as this one.

Nickel Steels.

Nickel steels have been in use for upwards of 30 years. Chronologically what is usually termed nickel steel was the fourth alloy steel to find industrial application. The steels to which this element is added aggregate a large tonnage. Their most marked characteristic is the wide range of composition over which alloys of industrial usefulness have been found to exist. *The compass is, indeed, greater than that of any other class of alloy steel.* It ranges from 1 to 74%, and embraces a great variety of structures.

Speaking generally, nickel raises the tensile strength of an untreated carbon steel, and in a still greater proportion the elastic limit for a given content of carbon without sensibly diminishing the ductility. It is this property more than any other which determines the special application of nickel steel to practical uses.

Steels low in nickel all possess pearlitic structures. They are mixtures of nickeliferous ferrite and pearlite which have undergone the gamma to alpha change in iron and the iron carbide inversion at a rather lower temperature than any plain carbon steels. The lowering is probably something of the order of 70° C. The important mechanical properties of such steels are due to two reasons : (1) The increased strength of the nickeliferous ferrite as compared with pure ferrite, and (2) the refining of crystal structure produced by the addition of nickel. The majority of these steels contain between 2 and 4% of the alloy metal. One of their most important applications is in the construction of bridges, particularly those of great span, and this is an interesting example to quote, because bridge steels of this character constitute the principal exception to the almost universal practice of using alloy steels in the heat-treated condition. Locomotive boilers constitute another use of the steel in the normalised condition. Gun steel contains 3.5% of nickel, and is always heat-treated. The same steel is also used in many automobile parts, since the variety of properties obtainable by modifying its heat-treatment renders it fit for almost any service demanding a strength and security from breakage which a carbon steel will not meet. Steels of the " martensitic structure " type find only a limited application in practice, on account of the fact that they are very hard and possess almost no ductility. They are difficult to work either hot or cold, but can be rolled if proper care is taken. The most noteworthy of these, judged from a scientific standpoint, is the 13% nickel alloy containing 0.55% of carbon, discovered by Arnold and Read.

High nickel steels containing 25% or more of nickel and of low carbon content are austenitic in structure at the ordinary temperature. Actually their structure is very similar to that of manganese steel, the main difference being that the former show no signs of twinning, whereas the latter do. These steels are costly on account of their large nickel content, but in spite of this they find certain applications on account of the variety of properties of the alloys. One of the most remarkable of them is " Invar," which contains 35% of nickel. This is used for making clock pendulums, and the balance-wheels of watches. The coefficient of expansion corresponds to an increase in length of 0.05 of an inch in a mile per °C.

Nickel-Chromium Steels.

Nickel-chromium steels are among the most important of all structural alloy steels. Their field of usefulness is continually being enlarged, not only by their encroaching on the uses of other lower tensile alloy steels. They are also invariably used in the heat-treated condition, for they are eminently susceptible to proper heat-treatment. Their mechanical properties can be varied within very wide limits. They can be obtained in a condition possessing great resistance to alternating stresses, and are, therefore, very suitable for the moving parts of machinery—*e.g.*, crankshafts—particularly where requirements are severe,

as in aero engines. In the past these steels have suffered to some extent from a liability to what is called temper brittleness. This term was originally applied by Mr. Dickenson[3], to denote the condition induced in these steels by slow cooling from the tempering temperature which is revealed by the low absorption of energy in the single-blow impact test of notched bars. Such steels, however, when rapidly cooled from the tempering temperatures are quite tough. These phenomena have been the subject of numerous investigations in recent years which have had for their object the desire to elucidate the cause, for not until this was known could a scientific remedy be applied. The work carried out by Dr. Greaves and Mr. Jones, under Dr. Moore's general direction, at the Research Department, Woolwich Arsenal, has been a most valuable investigation. To-day the problem hardly exists, since alloys can now be prepared which are essentially free from this drawback. A small quantity of molybdenum added to the alloy as a rule ensures freedom from temper brittleness. By the widespread use of nickel-chromium steels great improvements have been effected in the production of structures for various purposes, especially where saving of weight or increase of strength is important. The most conspicuous examples of these uses are in the automobile and aircraft industries. Heat-treated alloy steels with treble the strength of the simple steels they have replaced are now in regular use. They owe a part of their superiority to the presence of the alloying element, but still more to the care in heat-treatment which is given to them.

Heat-resisting Steels.

Finally, a word must be said on the subject of heat-resisting steels. Many of the requirements of modern engineering demand the use of metals and alloys which are capable of service above the atmospheric temperature and, indeed, at quite high temperatures. All alloys of iron are attacked more or less under such conditions, for the atmospheres concerned may consist of air, steam, carbon dioxide, sulphur dioxide, and, speaking generally, of furnace gases, which may vary considerably in composition. The majority of the steels which have been found resistant under these conditions contain chromium, and some of them contain nickel as well. Silicon also appears to be a valuable constituent of such steels. It would seem, therefore, that the resistance to corrosion conferred by chromium on steel at the ordinary temperatures which finds application in the manufacture of stainless steels is also retained by this metal at high temperatures.

World Production of Alloy Steels.

So far as I have been able to ascertain, with the exception of the U.S.A., no country publishes particulars of its production of alloy steels. It is, therefore, impossible to state what the world's production actually is at the present time. In 1925 about 2½ million tons of ingots and castings were made in the U.S.A. Ingots accounted for at least 95% of this. 80% of the steel was made in the basic open-hearth furnace, while electric steel was responsible for 12%. The production in America in 1928 had risen to about 4 million tons. It was probably at least 1½ million tons for the remainder of the world, making a total of about 5½ million tons. It is clear, therefore, that the alloy steel industry is one of considerable magnitude and far exceeds that of any other metal except carbon steel itself. That the above figures will be exceeded in the future, given reasonable economic development throughout the world, can hardly be doubted.

[We are indebted to the Mond Nickel Co., Ltd., for permission to publish this article, which has been specially written for them by Prof. Sir H. C. H. Carpenter, and will shortly be published by the Bureau of Information on Nickel, Thames House, Millbank, London, S.W. 1.—EDITOR.]

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[3] Journ. of the Inst. of Automobile Engineers, 1917-1, Vol. xii.

Furnace Electrodes

The quality of electrodes has a considerable influence on the operating costs of electric furnaces, and it is important that selection should be made according to the work to be done. Various aspects are discussed in this article.

ELECTRODES are essential for the operation of most electric furnaces, and a considerable quantity is necessary to meet requirements. In the production of aluminium, for instance, the amount required is nearly equal to the amount of metal produced—thus, the quality of electrodes can have a considerable influence on the operating costs of electric furnaces, and it is important that they should have some relation to the particular duty to which they are applied. In addition to the production of aluminium, electrodes play an important part in several industries, notably in the production of various ferrous and non-ferrous metals and alloys, and in the manufacture of various carbides in the electric furnace, while a considerable quantity is used in the electrolytic production of chlorine, caustic soda, and other substances. Their influence on production costs is appreciated, and many factors in their manufacture and use have been studied, but published information regarding them is somewhat meagre, due probably to the fact that the investigations are invariably carried out by manufacturers with a view to combining improvements in plant and processes with electrode practice. Certainly manufacturers of furnace electrodes have made continuous efforts to improve the quality of their products and at the same time lower the cost to the consumer.

The carbon family has three main divisions, comprising amorphous carbon, graphitic carbon, and crystalline carbon. Chemically, these are all carbon, but they differ greatly one from another in their properties. To the amorphous carbon group belong the common forms of carbon, such as coal, coke, charcoal, gas retort carbon, lamp-blacks, etc. Graphite, both natural and manufactured, forms the second group, while the diamond is the representative of the crystalline group. Electrodes may be composed of either amorphous or graphitic carbon. The chief materials used, according to Vosburgh,[1] are high-grade anthracite coal, selected primarily for strength of particle ; petroleum coke of low ash content ; and hard and soft pitch. All these materials are used in making carbon electrodes, the latter ones in making cokes electrodes which are to be graphitised, and for carbon electrodes used in the production of aluminium. Both the anthracite coal and the petroleum coke are treated at a high temperature to drive off volatile matter and to induce shrinkage, but primarily to reduce the electrical resistivity to a low value. After calcination, both materials are ground to pre-determined sizes, depending upon the size of the electrode to be made, and mixed with exact quantities of pitch in heated mixers.

The green mix may be extruded through dies under high pressure or moulded under pressure to form the green electrodes in any one of the many sizes now required by a varied trade. The green electrodes must be made to an exact size with proper allowances for the shrinkage that occurs in the baking and graphitising processes. The dies are machined most accurately ; in fact, usually hand-finished to templates, as the flow of materials through them must be controlled exactly to give a suitable finished product.

In the green form the electrodes are packed in furnaces surrounded by fine coke, which supports them during the preliminary softening period as the heat is applied, and are baked to a final temperature of 1,000° C., the temperature being raised gradually to the maximum. Baking and after-cooling may occupy up to five weeks. After baking, they are cleaned by hand to remove the packing coke, and are inspected carefully for every one of a possible dozen or more faults. The coal carbon electrodes are sent to storage or to the threading and finishing department. The coke electrodes are ready to be graphitised.

The graphitising process invented by E. G. Acheson is generally familiar. In this process the carbon material of electrodes is wholly changed into graphitic carbon through raising it to a temperature of at least 2,200° C. by the heat generated in passing current through the material, which acts as a resistance body. The material is packed closely in large open furnaces and covered with coke. The current is supplied through huge contacts at the furnace ends ; by manipulation of the current control the temperature is regulated and generally brought to the desired maximum. The complete process of packing, graphitising, cooling, and unpacking, occupies from a week to ten days. After slow cooling the electrodes are cleaned and stored or machined, as required, for their various uses. They can be made in practically any shape and size up to a maximum of about 40 in. in diameter for carbon and 18 in. for graphite. Although graphite electrodes cost more than carbon electrodes of the same dimensions, the electrical resistivity of graphite electrodes is much lower than that of carbon, hence graphite electrodes are smaller than equivalent carbon electrodes. A comparison between graphite and carbon electrodes, given by Lister,[2] is as follows :—

	Acheson Graphite.		Non-Graphite Carbon.
Specific resistance in " ohms " per cub. in.	0·00032	..	0·00124
Comparative sectional area for same voltage drop	1·0	..	3·8
Weight in lb. per cub. in.	0·0574	..	0·0564
Tensile strength in lb. per sq. in.	800–1,000	..	1,000–1,500
Temperature of oxidation in the air	640° C.	..	500° C.

In an investigation to determine the maximum current carrying capacity of furnace electrodes, Bailey and Ridgway[3] state that the performance of electrodes carrying power into a furnace is influenced by many variables, difficult to define and control. In the simple case of a single-phase open-top furnace equipped with two vertically pendant electrodes, it is recognised among operators that the smoothness of operation of the furnace, rate of charging, and evolution of gas from the furnace reaction, may be as effective in controlling electrode performance as electrical conductivity.

[1] F. J. Vosburgh, Elect. Eng., Dec., 1933.

[2] Walter Lister, " Practical Steelmaking," pub. Chapman and Hall, Ltd., pp. 338.

[3] B. L. Bailey and R. R. Ridgway, paper before gen. mtg. Electrochem Soc., 1933. Preprint. 63.

Erosion by oxidation lowers the cross-section which reduces the carrying capacity of the electrode. The increasing heating of that part of the electrode where erosion is greatest, because of the greater electrical losses at this part, causes more oxidation, resulting in the cumulative effect known as " necking." Because of the wide variation in temperature to which electrodes are subjected in service on account of variations in furnace-operating conditions, a big quality electrode must resist surface oxidation. Much attention, therefore, has been directed to the preparation of electrodes which will resist surface burning, and various methods have been adopted by manufacturers to improve the surface resistance of their products. An important factor is the maintenance of a high density in the electrode, which, in general, has the lowest electrical resistance. It is generally assumed that a porous electrode will oxidise more rapidly than a dense electrode at equal surface temperatures, thus, if two electrodes of equal cross-section are used with the same current density, the more porous electrode, assuming other factors are equal, will have a higher electrical resistance, and will cumulatively be subject to greater erosion because of the increased surface temperature caused by the greater electrical losses per unit volume of the electrode.

It is probable that some will disagree with the natural conclusion from the above discussion that high electrical conductivity is more desirable in an electrode. There are furnacemen who claim superior results with electrodes which do not have a high electrical conductivity. One explanation given is that the thermal conductivity of the electrode must also be taken into consideration. An electrode with high electrical conductivity also has high thermal conductivity. It is claimed that, if an electrode is heated to a high temperature at one end, the thermal conductivity along the axis of the electrode will be as important in the limiting current at which the electrode would start to oxidise as the heat liberated within the electrode. An exact theoretical analysis of this hypothesis cannot be made until exact figures for the thermal conductivity of furnace electrodes of the standard commercial types are available. The data for these constants at present in the literature are in wide disagreement. Most of the claims of actual improvement in electrode service by using electrodes of poorer conductivity have been made as a result of so-called practical plant tests, but the factors serving to bring about low electrode costs are so many and varied that tabulated data for any given plant are meaningless for other plants using different electrode practices and furnace assemblies.

In the investigation by Bailey and Ridgway, standard carbon and graphite electrodes were studied, ranging in size from 7 in. to 12 in. in diameter. They were studied with reference to the alternating current conductivity measured along the electrodes and through the joints. Actual a.c. resistances were compared with the relative claims of current-carrying capacity of these electrodes for the given sizes. Measurement was made of surface temperatures and power losses along electrodes carrying actual rated currents. The results of this investigation show that the highest resistance in the electrode is at the joint, even when extraordinary precautions are taken to make excellent joints. The hot resistance of the electrode is shown to be less than the cold resistance. It is also shown that a very high power loss may exist at the contact surface of the water-cooled electrode clamps, even when these are kept in good condition by polishing. Carbon electrodes recommended for high-current density were found to be superior to standard products.

It is now more generally appreciated that proper electrode assembly is of great importance, particularly in the case of carbon electrodes which require jointing paste, in keeping the electrode consumption within reasonable limits, and some means of checking the assembly should be adopted. Even with the maximum amount of care, consumption per ton of product varies widely, depending on the nature of the process and the relative size of the equipment, but the ability of the operator has a considerable influence, and with proper skill can effect much saving of the electrodes.

With regard to the uses of graphite and carbon electrodes there are wide differences in practice, but generally the former are preferred for electrolytic operations, because there is much less oxidation of the carbon in the electrolyte in comparison with the carbon electrode. Generally for electrolytic work carbon electrodes are unsatisfactory. For electrothermic work, however, the division of the two types of electrodes is not so well defined, the choice depends upon the nature of the process and the result desired, and frequently is simply a question of cost, in which case the carbon electrode is generally the more economical. In the production of aluminium, for instance, carbon electrodes are almost invariably preferred, because in the production of every pound of aluminium ¾ lb. of electrode is used ; in the carbide industry also carbon electrodes are generally given preference ; the same applies to the ferro-alloy industry, though for high-grade alloys both graphite and carbon electrodes are used, the latter giving excellent results in the production of low carbon, rustless and similar steels.

Procedure Handbook of Arc-welding Design and Practice.

A REVISED and enlarged edition of this book has been reissued because of the demand which exhausted the original issue published last autumn. The new volume is greatly enlarged and encyclopædic in scope and contents. It contains over 450 pages with several hundred illustrations. The eight principal sections deal with various phases of arc welding in a simple, concise manner, well illustrated with detailed drawings and photographs. Taken together, they cover practically every use and application of arc welding.

Among the many additional features which have been included in the new edition are weld inspection (visual, stethoscopic, electro-magnetic, X-ray, and Gamma ray) ; study of stress distribution by means of polarised light ; a simplified method for the design of arc welded machinery ; procedure and speeds for arc welding aluminium ; technique and speeds for welding of copper ; construction of welded water lines, etc.

Apart from the value of the book as a practical guide to anyone interested in welding, it serves as a handy reference work for estimators. Complete welding speed tables and information make it a simple matter to estimate welding costs. Among the subjects treated in detail are descriptions of various welding processes, definition of welding terms, classification of welds, strength of welded joints, methods of stress relieving, tabulations of speed of welding all types of joints in all positions, methods for estimating cost of weld production, structures and properties of weld metal, specifications for steels and alloys of good weldability, the welding of non-ferrous metals, comparison of limitations of rolled steel and cast iron in machine design, construction details of basic machine parts built by welding, treatise on fundamental advantages of arc welded and revited steel structures, details of structural arc welding, welding of automotive parts, construction and repair of bridges, use of arc welding in cement plants, gas plants, machine shops, mines, refineries, pipe lines, railroad shops, steel mills, shipyards, and hundreds of other interesting subjects.

The book is designed especially for the use of designers, engineers, welding operators, welding foremen, and for engineers responsible for the design of products which may be redesigned for welding construction. It is of a convenient size and bound in semi-flexible simulated leather embossed in gold.

By A. F. DAVIS, published by The Lincoln Electric Company, Cleveland, Ohio, U.S.A. Price $1.50, post paid in the United States ; foreign postage, 50 cents extra. Copies are obtainable from Buck & Hickman, Ltd., 2, Whitechapel Road, London, E. 1.

Industrial Economy Suggestions

By GLYN POWIS

In this article the writer deals with a few typical examples of industrial circumstances where careful consideration, coupled with a little wise spending, can result in appreciable saving. He points out, however, that stinting the outlay may result in disappointment, and may fail to repay the efforts expended.

IT was inevitable that the lean days through which industry has been passing should bring in its train a general desire, if not necessity, to effect economies in manufacture wherever opportunity presented itself. With the outlook at present appearing to hold greater promise, those desires are in many instances being brought into being. It is becoming apparent, however, in some quarters, that while the advisability for such action is fully recognised, the efforts made are half-hearted in character, and result in a certain amount of expenditure without the hoped-for benefits accruing.

Furnace Insulation.

One of the first items where much money can be saved is the industrial furnace. Because this unit usually performs satisfactorily, one is apt to overlook the heat losses by radiation which obtains on a high proportion of them. The remedy for this is to use insulation.

Most electrically-heated furnaces are insulated to a certain extent as their method of heating lends itself to the easy incorporation of such protection. Those of the gas, oil, and solid-fuel types, however, seldom have sufficient insulation to effect the full economies of fuel possible, yet as much as 20% saving in fuel can often be brought about by its use.

For best results, insulation in the form of bricks should be used not only because this form has usually the greatest heat-loss resistance, but also because they are laid more easily than other forms, and therefore involve less labour costs for fixing. The mistake to avoid is making the wall of insulation too thin. While the labour cost is being incurred, the extra thickness of wall is well worth the installation, and although the initial cost of material is greater, the more definite saving which will result defrays such extra cost in less time than a lower saving would defray a slightly lower cost.

Improved Steels.

It is difficult to believe that some firms, usually the smaller ones, still cling to straight-carbon steels for the whole of their requirements in the way of dies and tools, in spite of the advantages to be gained by the use of those of improved quality.

Price is the reason most usually put forward by such people for their non-usage of alloy steels. In some instances, this may, at first sight, appear a formidable obstacle, especially in cases where, say, for example, an alloy die-block steel may have a basis cost of 1s. per lb., as against approximately 2d. per lb. for a 0.60% carbon steel. But costs should not be compared in this manner. In the first place, at the time the steels are received the alloy quality would be six times the cost of the other, but with a die-block of 100 lb. in weight, by the time both have had the impressions sunk the higher priced tool will have cost little more than twice the lower-priced one, because toolmaking and machining costs the same for both, and so reduces the price ratio.

Secondly, a die-steel which commands a selling price of 1s. per lb. will usually give a life of much more than twice that of a carbon steel and, therefore, the true cost for comparison is that of unit production. This figure, and this only, is capable of giving a true representation.

Where a user has not only the conviction of success ahead, but also the patience to continually try different types of alloy steel for a certain purpose, the cost of production will be lessened to almost unbelievable extents. It is as well to remember that there are but few tools to-day made of carbon steels which cannot be made with greater advantage of *some* type of alloy or special steel. At the same time, it is often the case that any one particular type of alloy steel, as for example hot working, will not suit all hot-working requirements, and the best way of determining the most suitable type for any given requirement is by trial and error.

Before leaving the question of alloy steels, an actual example of cost reduction by the use of such may be of interest.

The operation involved was one of drifting holes in steel forgings wherein a working temperature of approaching 450/500° C. was attained in dies and drifts. The steel employed for the die was Nitralloy, grade 1. Previously the dies had been made of C. ·50/·60% steel used in the as-forged condition. The basis costs of the respective steels were 8·7d. per lb. and 2·3d. per lb., but after the former had been nitrided, the reduced weight of the finished die when gasified at the standard charge increased the cost of the original die-block by 3·4d. per lb., making in all a gross cost of 12·1d. per lb.

From these figures the cost of the nitrided die steel was 5.26 times that of the normal carbon quality. When the unit cost of production was recorded, however, obtained by charging all costs to the respective dies and dividing the total of such costs by the amount of work produced, it was revealed that the figure for carbon dies was ·047d. per hole drifted, as against ·024d. per hole for the Nitralloy material. It will be seen, therefore, that, in spite of the higher outlay, Nitralloy steel, in this particular case, cut down the production costs to very nearly half those which previously operated.

Other instances where alloy steels are able to effect considerable savings are in the use of special heat-resisting and non-corroding steels for hardening and annealing cans, pyrometer sheaths, high-temperature furnace metal-work where affected by heat, conveyor mechanism for continuous furnaces, and metal containers for chemical plant. Not only the point of view of costs saving, but sheer necessity in order to cope with working conditions often makes the adoption of such steels essential to-day.

Machinery and Layout of Plant.

Amongst the plant itself an item which will often bear investigation is that of attempting to run-worn-out machinery. Reckon up the amount of time spent by fitters in repairing these. Take into consideration the " idle-time " paid to the operatives who may not be on piece-work. Think of the extra time or plant involved in producing your requirements to schedule—and then go out and see if you can persuade some machine manufacturer to sell you a machine on hire-purchase terms.

In regard to layout, it has been proved worth while to rearrange machinery and plant in order that a cycle, or cycles, of operations may run in sequence in order to avoid loss of time and labour in moving semi-manufactured goods unnecessarily.

Wherever possible, suitable types of conveyer mechanism should be installed, as this facilitates movement of goods at a minimum of cost. So many excellent types of mechanical transport are now available that there are few trades where use of some, at least, cannot be made without considerable advantage.

Production Costs.

Where dies and tools are used in large quantities for production purposes, it pays to have a capable person recording the individual life of each. Serial numbers should be allotted on manufacture or issue, and thus provide satisfactory means of identification. If a particular type of steel produces a poor result, drop it in favour of another, and by a gradual process of elimination pick out the type most suitable for the purpose involved. By the same means, variations in heat-treatment may be experimented with, restraint placed upon careless or destructive workers, mislaid tools sought after and found, and the possibility of pilfering be reduced to a minimum.

An item concerning labour which affects production costs is that of working batches or gangs of men on one machine or on several machines which embrace a cycle of operations. If the men are paid by the hour (daywork), any breakdown which may occur is likely to prove a costly business. Gangs of men should be on a piecework basis, if at all possible, or arrangements should be made so that the interruption of one member of the party will not enforce the others to cease work.

A simpler matter, which may even cause amusement on reading in this text, is that of the choice of first-aid men. Avoid choosing a man who is one of a pair who work together, otherwise, it will cost just double what it need do to carry out this humane work. The writer is familiar with a case where such conditions existed for some years before the demands of economy called for close examination of all such details.

One place where economy should not be given too free a hand is the laboratory. If materials are not always checked on arrival, the danger of inferior quality being passed for manufacture is very real. Sooner or later the inferior material will reveal itself either in course of manufacture of goods or in their subsequent use, and one usually finds the cost of putting right such troubles infinitely greater than the cost of the works chemist or one of his assistants.

Research Committee on Effect of Temperature

THE Joint ASTM-ASME Research Committee on Effect of Temperature on the Properties of Metals, which met in Washington during March 5 to 9, prepared last year tentative " codes of recommended practice " for the making of short-time high-tenperature tensile tests, and long-time or " creep " tests. Adherence to the principles described in these codes is likely to enable different laboratories to secure consistent and reliable results. In order that such consistency may be demonstrated, and in order to aid laboratories in achieving consistency, there has been a demand for a " standard " material to use in cross-checking results from different laboratories. To meet this demand the Joint Committee is having prepared, through the courtesy of the Bethlehem Steel Corp., a supply of 0·40% carbon open-hearth steel, specially made, selected, annealed, and tested so that the supply is of an extreme degree of uniformity, and thus suitable for cross-checking or so-called " calibration bar " purposes.

The Joint Committee will supply this steel to those laboratories interested in finding out how well their short-time and/or creep tests agree with those from other laboratories. Such co-operating laboratories will agree to make the comparison creep tests at one temperature and load, and for the length of time selected by the committee, and the short-time tests at a few selected temperatures,

recording all the data required by the codes in order to show that at least the minimum precautions for accuracy required by the codes have been observed. Sufficient material for duplicate tests will be supplied if desired. The A.S.T.M. headquarters can supply at nominal cost pads of forms for reporting data, which workers in this field will find convenient not only for this report but for regular use. The results will be summarised and, when enough data are in, published, each laboratory being designated only by a symbol.

The Achema Exhibition.

A SERIES of meetings of scientific societies will be held in the Exhibition Buildings at Cologne from May 18 to 27, 1934. These meetings will be a centre of technical activity and interest. Three large exhibition halls are to be filled with examples of the latest developments in technical plant, apparatus, and accessories. We understand that over 250 firms will be exhibiting the latest improvements and discoveries in technical development ; these will embrace the whole field of pure and applied science and will be of considerable interest to both users and manufacturers. About 15 scientific and technical organisations will be holding meetings in Cologne or at Bonn at the same time, among them the Deutsche Bunsen Gessellschaft, which is holding its annual meeting at Bonn, May 17 to 19 ; the annual meeting of the Dechema, Deutsche Gessellschaft für Chemisches Apparatewesen, will be held in conjunction with the annual meeting of the Verein deutscher Chemiker at Cologne, May 23 to 25 ; at the latter meeting the subject for consideration will be " Scientific and Technical Centres of Research in Chemical Engineering."

Making Super-quality Steels.

(Continued from page 170).

On an equipment of this size a number of protective devices are necessary, and ample provision has been made to render the circuit dead in the event of faults or operating errors. For instance, the furnace coils are water-cooled, and would therefore be seriously damaged if the water supply failed for any appreciable period. Consequently, relays are placed in the water circuits to prevent the operator from closing in on the high-frequency circuit or to render the circuit dead should the water supply at any time be insufficient. Red and green indicating lamps are provided to show if the water supply is adequate, and at the same time a number of other red lamps are connected so as to indicate other faults on the circuit, such as the failure of the water-cooling supply to the machine bearings or undue over-heating of any particular part of the gear.

The whole of the electrical installation has been designed by Messrs. Campbell and Gifford, in close co-operation with Samuel Fox and Co., Ltd., engineering and research staff. The equipment has been supplied by the Electric Furnace Co., Ltd., of 17, Victoria Street, London, S.W. 1, acting in conjunction with Metropolitan-Vickers Electrical Co., Ltd., Trafford Park, Manchester.

The United Steel Companies, Ltd., are to be congratulated on the progressive policy adopted. It had its inception some years ago, when trade was probably at its worst, and embraced a comprehensive reorganisation scheme of which this new melting plant is only a part. Mention might also be made of the central research laboratory, which, when completed, will be one of the most advanced of its kind, as an indication of the faith of the Directorate in the recovery of the British steel industry. The steps taken by the Directors at that time show that they were not lying down meekly under the imputation of inadequacy or inefficiency, nor were they lying supine and indifferent under the great economic difficulties through which they were passing. That success has resulted from their foresight is indicated by the fact that production is proceeding on record lines in order to satisfy increasing demands.

Analytical Control of Cadmium Electro-Plating Solutions

By E. E. Halls.

" Cadmium is a comparative newcomer as a protective coating, but its close proximity to iron in the electro-chemical series indicates less chemical reactivity than zinc or a lower corrosion rate. It is applied mainly as an electro-deposit or plating, and although coatings that are but a small fraction of a thousandth of an inch in thickness are all that is requisite, its rapidly increasing use has elevated this process from a laboratory experiment to an important industrial application." In this article the author stresses the necessity of analytical control to ensure the maximum utility of the cadmium plate.

IN modern electroplating installations, periodic analysis of the plating solutions is recognised as an integral part of control. Without this assistance from the works chemist, it is not too far-reaching a statement to make in asserting that not only reliable quality in repetition work is impossible, but also that costing becomes fallacious. Cadmium plating is not merely without exception to this rule, but in fact, cadmium plate of any utility at all is almost impossible to produce in the absence of analytical control. It is due to cyanide electrolytes being invariably employed that anode efficiency always exceeds cathode efficiency, and that cyanide is easily susceptible to oxidation with resultant decomposition. Consequently, the cadmium content of the solution at first rises excessively, and then, with falling cyanide concentration, rapidly decreases, the cadmium becoming precipitated as a dirty brown sludge. The object of analytical control, therefore, is to reveal the precise condition of the electrolyte composition, in order that these tendencies may be checked by appropriate control of current densities, electrode areas and spacings, and chemical additions.

Although the commercial practice of cadmium plating has been established for some years, the literature relating to analysis of cadmium solutions is scanty and somewhat indefinite, and a real need exists for a scheme for determining the essentials by methods which combine rapidity and accuracy. As fairly wide variations are permissible in working, it may be claimed that the degree of accuracy required is not great. Be this as it may, it must be stressed that the methods utilised must be absolutely reliable, capable of repetition with identical results. The procedure described below is claimed to fulfil these requirements, and has proved itself over an extended period in the busy sphere of an engineering works laboratory, in which services to the electroplating shop only represent one of numerous activities.

The determinations that the chemist is called upon to make comprise :—

(a) Total cadmium content.

(b) Free cyanide content—viz., the alkali cyanide present in excess of that required to retain the whole of the cadmium in solution as double cyanide Cd (CN)2–2NaCN.

(c) Alkalinity, present as hydroxide and carbonate.

Procedure.—Before proceeding with any determinations, the plating solution is filtered if necessary, the first 20 c.c. passing through the filter being rejected.

The residue will consist of iron as basic oxide, cadmium as basic carbonate or cyanide, and extraneous dirt. If necessary, it may be analysed by redissolving the residue from a measured volume of solution through a weighed filter paper in dilute sodium cyanide solution. Any insoluble residue consisting of dirt and iron is thoroughly washed, dried at 110° C., and returned as insoluble matter. Cadmium is determined in the filtrate, and expressed as carbonate.

Iron may be present in the solution, entering with work or from anodes and tank. It does not interfere with the determinations, except volumetric cadmium. For general practice, its presence may be neglected, but if desired, it may be removed with ammonia after the sulphuric acid treatment for volumetric cadmium.

Total Cadmium Content.

The volumetric method is the more rapid of the two given, but the electrolytic method should be used periodically as a check.

Electrolytic Determination of Cadmium.—A 25-c.c. portion of the plating solution is diluted with water to 180-200 c.c. and electrolysed at laboratory temperature, using a rotating platinum cathode, the latter being in the form of gauze or wire spiral. The current conditions must be 0·5 to 0·7 amperes at 4·5 to 5·0 volts for the first four to five hours, and 1·0 to 1·2 amperes for a final one to one and a half hours. At the end of this period, the cathode is removed, rinsed in distilled water, then in alcohol, and dried over a hot-plate or in an oven at 110° C. prior to weighing. Completion of deposition should be ascertained by returning the cathode and continuing electrolysis for a further half-hour period. The deposit of cadmium should be clean, bright, and whitish grey in colour.

For convenience in removing the electrodeposited cadmium from the platinum cathode, it is strongly advocated that a flash coating of copper be deposited electrolytically before depositing cadmium upon it. A hot solution of 5% copper sulphate, and 0·5 ampere current density serves for this purpose, the coated cathode being rinsed and dried as above before weighing.

From the weight of cadmium deposited (*a* grams) cadmium content of the plating solution is computed as follows :—

Cadmium content per gallon = 6·41 *a* ozs.
Cadmium oxide content per gallon = 7·33 *a* ozs.
Cadmium sodium cyanide content per gallon = 14·96 *a* ozs.

Volumetric Determination of Cadmium as Ferrocyanide.

Solutions required.—The solutions required are standard potassium ferrocyanide, made up by dissolving 22·5 grams of pure potassium ferrocyanide crystals, K4Fe(CN)6–3H2O, per litre of water, and saturated uranium acetate or nitrate solution as indicator.

Standardisation of Ferrocyanide. About 2·5 grams of pure cadmium metal are accurately weighed and dissolved in 10 c.c. dilute nitric acid. After cooling, 20 c.c. concentrated sulphuric acid are added, and the mixture evaporated to fumes. Meticulous care must be given to avoid loss by spraying or sputtering. The solution is cooled and made up to exactly 250 c.c. with water.

For the standardisation of the ferrocyanide, a 25-c.c. portion of the pure cadmium solution is employed ; it is diluted to approximately 300 c.c. with hot water, and 5 c.c. concentrated hydrochloric acid, and 12 grams ammonium chloride added. It is titrated hot at 80/90° C. with vigorous stirring, the uranium solution serving as external indicator, end-point being decided by the formation of a brown colouration during the first few seconds (maxi-

mum five) of mixing a drop of the solution with a drop of indicator. In any case, upon continued contact a brown colour develops.

It should be remarked that some doubt exists in deciding the end-point when the worker is new to the process, but a few preliminary titrations serve clearly to establish the point. Dilution and temperature of the cadmium solution are essential features to the rapid precipitation of the cadmium ferrocyanide; if the solution is cooler than specified, considerable time elapses before this is effected. Also the end-point colour is rendered more distinctive if a small drop of saturated uranium solution be employed, and if the drop of dilute test solution is made to merge into it, rather than if a larger quantity of more dilute indicator is employed.

Determination of Cadmium in the Plating Solution.— To 10 c.c. of the sample in a 250-c.c. conical flask, 5 c.c. of concentrated sulphuric acid are added, under a good hood, and the mixture is evaporated to fumes. Meticulous care must be exercised for the avoidance of loss by spray. In the event of persistent blackening occurring due to high dextrine content, or presence of other organic matter, 5 c.c. concentrated nitric acid and 5 c.c. sulphuric acid may be added after cooling, and the evaporation repeated. This is not usually necessary. The cooled residue is diluted to 300 c.c., approximately, with water, 5 c.c. of strong hydrochloric acid and 12 grams of ammonium chloride added, and the mixture heated to 80-90° C. Titration with the standardised ferrocyanide is then carried out as above. This procedure neglects the presence of iron which is usually present in amounts small enough to neglect correction for, and which may be separately estimated, if required.

Results are computed as follows :—

If *a* is the cadmium equivalent in grams per c.c. of ferrocyanide solution, and *b* c.c. are required for 10 c.c. of the sample :—

Cadmium content per gallon = 16·0 *a b* ozs.
Cadmium oxide content per gallon = 18·3 *a b* ozs.
Cadmium sodium cyanide content per gallon = 37.4 *a b* ozs.

Free Cyanide Content.

Reference is made by platers to combined and free cyanide, and some looseness arises owing to the fact that the function of alkali cyanide in different metal plating vats varies somewhat according to the metal concerned. In cadmium solutions, cadmium is held in solution by virtue of the solubility of cadmium cyanide in alkali cyanide, two molecules of the latter being required for each of the former. (Cd $(CN)_2$. 2 KCN.) Thus, it is clear that for each molecule of cadmium oxide employed in the make-up, four of sodium cyanide are necessary for its solution, and these should be regarded as combined. Excess beyond this amount may on the same argument be regarded as " free."

Combined cyanide may, therefore, be calculated from the cadmium figure (the latter, of course, being assumed totally in solution ; sludge or sediment having been removed before test) as already indicated in the computations under the previous section.

Free cyanide may be arrived at by direct titration with $\frac{N}{10}$ silver nitrate solution (16.99 grams pure silver nitrate crystals dissolved per litre of distilled water), the procedure being as follows :—

A 10-c.c. portion of the plating solution is diluted to about 40 c.c. and titrated cold with N/10 silver nitrate in the usual manner, the end-point being determined by the first formation of permanent turbidity.

Results are computed as follows :—

If *a* is the sodium-cyanide equivalent in grams per c.c. of the silver nitrate solution, and *b* c.c. are required for 10 c.c. of sample :—

Free sodium cyanide content per gallon = 16·0 *a b* ozs.

Alkalinity.

Alkali cyanide, hydroxide and carbonate are the chief items contributing to alkalinity, and the first of these having been ascertained, estimation of the latter two suffices. These are arrived at from two tests—one being an acid titration which measures the hydroxide plus half the carbonate, and the second the carbonate, from which the two separate constituents may be computed. However, in practical control work for determining the necessity or otherwise for caustic additions, the first of these operations alone proves sufficient.

(1) *Volumetric determination of alkali equivalent to alkali hydroxide, plus half the alkali carbonate.*—To 10 c.c. of the plating solution in a 600-c.c. beaker is added silver nitrate solution in slight excess over that required for complete precipitation of the whole of the cyanogen radicle as silver cyanide. The volume of silver necessary may be calculated directly from the titrations *a* and *b*, or estimated as follows :—

Add 25 c.c. N/10 silver nitrate solution per ounce of cadmium per gallon (titration *a*), plus 14 c.c. N/10 silver nitrate solution per ounce of sodium cyanide per gallon (titration *b*). This allows 10 % excess silver nitrate.

The mixture is diluted to 200-400 c.c., according to the bulkiness of the precipitate, and titrated with N/4 standard sulphuric acid, using phenol phthalein as indicator. It is necessary to stir vigorously during additions. The end-point is that of complete disappearance of pink colour from the solution, and it is safe to stipulate that the disappearance should be for at least one minute. Care must be taken that the end-point is not passed, as the silver cyanide in suspension assumes a pinkish colour, but if dilution is correct, this rapidly coagulates and settles, and does not mask the end-point.

When this determination is deemed sufficient, the results are computed as follows :—

If *a* is the sodium hydroxide equivalent in grams per c.c. of the N/4 sulphuric acid solution, and *b* c.c. are required for 10 c.c. of sample :—

Alkalinity, expressed as sodium hydroxide per gallon = 16·0 *a b* ozs.

2. *Volumetric determination of alkali present as carbonate.* —10 c.c. of the plating solution in a 600-c.c. beaker is diluted to 200-300 c.c. with water and precipitated hot (at 40-50° C.), with a slight excess of 10% barium chloride solution. The barium carbonate is allowed to settle, filtered and thoroughly washed with hot water. The filter is placed in 100 c.c. of water, and an excess of approximately N/4 hydrochloric acid added. Carbon dioxide is removed by boiling gently. Excess of acid is back-titrated with N/4 standard alkali hydroxide, phenol phthalein as indicator. By performing a blank on the same volume of acid, standardisation of the latter is procured under the same conditions.

Results are computed as follows :—

If *a* is the sodium carbonate (Na_2CO_3) equivalent in grams per c.c. of standard alkali solution, and *b* c.c. is the difference between blank and actual titrations, working on a 10-c.c. sample :—

Sodium carbonate content per gallon = 16·0 *a b* ozs.

3. *Calculation of alkali present as hydroxide.*—From total alkalinity in ounces per gallon (P) as determined in C.1, and carbonate alkalinity in ounces per gallon (Q), as determined in C.2. the alkali present as hydroxide may be calculated as follows :—

Sodium hydroxide content per gallon = (P − 0·378Q) ozs.

The volumes of plating solution sample specified in each test are based on the average type of electrolyte made up from four to six oz. of cadmium oxide and 12 to 16 oz. of sodium cyanide per gallon. They may readily be adjusted as shown by experience for other proportions.

The above-described processes will no doubt prove of value to many chemists engaged by electroplaters, and in numerous engineering industries, in addition to providing assistance in the development of this particular plating process.

Review of Rustproofing Processes with Reference to the Use of Town's Gas

By O. W. Roskill

A GREAT deal of research work has been devoted of recent years to the subject of corrosion resistance. When it is considered that the objects to be treated may vary in size from a small screw to a gasholder it will be realised that the methods employed must also vary considerably. All such methods, however, may be divided roughly into two classes : one in which there is an actual physical deposition of the protective coating on the surface of the metal, for example in metal spraying and the application of paints and lacquers ; and the other in which the surface of the metal itself is transformed chemically into a rustproof coating, as in the Parker or Coslett processes in the case of iron and steel, or anodic oxidation in the case of aluminium. The first class may be further subdivided according to whether or not there is any chemical combination between the metal to be protected and the protective material ; considering iron and steel only, in the case of plating and painting there is usually no such combination ; in the case of sherardising, and probably also metal spraying—at any rate with some protective metals—there is. The dividing line here, however, is not very sharply defined.

Whatever method of rustproofing is adopted it is essential that the parts to be treated should be absolutely clean and free from grease or oil. The solvent now most commonly used for this purpose is Trichlorethylene, by means of which it is possible to produce clean dry parts, at the same time recovering most of the oil and grease removed. Imperial Chemical Industries, Ltd., have produced several types of plant using this solvent, both in the liquid and vapour state. No agitation is necessary, so that the surfaces are not damaged nor is there any risk of fracturing delicate parts.

Standard models are made in various sizes and may contain one, two, or three cleaning chambers. Where two chambers are used, the first contains trichlorethylene liquid and the second trichlorethylene vapour. The parts to be cleaned are placed in a suitable cradle or metal basket, and are immersed in the liquid chamber for about a minute, after which they are transferred to the vapour chamber where they remain for about 2 minutes. They are then entirely free from oil and dirt. The correct temperature throughout the process is maintained thermostatically in the case of gas-heated plants. Cooling water is circulated through coils to prevent the temperature rising too high, and this provides a convenient check on the correct working of the plant, as the outlet water should not be allowed to become too hot to touch.

The method of heating used by any particular works is determined, of course, by the other plant in conjunction with which the degreaser is to be worked. If steam is always available, this is the cheapest method, but there are many works where it is not, and in connection with rust-proofing town's gas is largely used. The consumption varies with the size of plant ; but in the case of the standard model whose effective internal dimensions are 3 ft. 6 in. long, 1 ft. 9 in. across, and 1 ft. 6 in. deep, heating is effected by means of a 4 ft. single-bar gas burner, perforated along 3 ft. 6 in. of its length. The gas consumption in this case is about 85 cub. ft. per hour at 4–5 in. water gauge. The water consumption in the cooling coils is about 50 gals. per hour. An interesting type of degreaser made by Imperial Chemical Industries is one for use where the L.C.C. petrol regulations are in force. Although heated by coal gas, the apparatus is completely flame-proof, and may be used with safety in an atmosphere containing petrol or other inflammable vapour.

After cleaning, the articles are ready for any of the following methods of rustproofing. Degreasing is, of course, not always necessary. Machined parts are usually degreased ; castings are sometimes metal-sprayed, for instance, after just brushing over. Pressed sheet—e.g., mudguards—is sometimes degreased and sometimes not prior to enamelling.

Metal Spraying.

Metal spraying as a method of rustproofing is the process by which any metal capable of being melted in an oxycoal gas, oxyhydrogen, or oxyacetylene flame is deposited by means of a special pistol on the surface of the object to be treated. The thickness of the metal deposited is only limited by individual requirements, and although a thickness of 0·004 in. of zinc coating is adequate for the prevention of rust in most cases, coatings up to $\frac{1}{8}$ in. thick have been applied to certain large tanks. An important feature of this process is that the pistol will successfully deposit aluminium, a metal which has so far defied all attempts at electrolytic deposition. A variety of metals may be used : zinc for atmospheric corrosion ; aluminium for sulphurous corrosion ; lead and other metals for corrosion by certain chemicals. Aluminising, or aluminium spraying, gives a good protection against scaling and corrosion up to temperatures of about 975° C. As examples of this, it has been adopted by the Air Ministry as the standard method of protection for aircraft exhaust pipes, which are subjected to atmospheric corrosion as well as to high temperatures ; and it is also used for protecting pots in cyanide and salt-bath furnaces, resulting in considerably increased life. As no vats or tanks are required in the process of metal spraying, the size of objects which may be treated is unlimited. A sluice gate at the Porte de la Villette in the Saint-Denis canal, Paris, was sprayed with zinc in the year 1922. It has never been re-sprayed, and is still in perfect condition, although it has been alternately subjected to the corrosive influence of air and the water of the canal. The process is controlled in this country by the British Oxygen Co., Ltd.

The equipment for metal spraying consists of a small and easily manipulated pistol which weighs 3½ lb. The requisite metal in the form of wire, which is usually 1 mm. in diameter except in the case of lead or tin, when the diameter is 1·5 mm., is fed into the pistol and melted in a flame produced from a combustible gas. The oxygen for combustion is supplied from the usual commercial cylinders fitted with a regulator to give pressures up to 30 lb. per sq. in. If hydrogen or acetylene is used as the combustible gas, this is also taken from cylinders, but if town's gas is used it is generally supplied by means of a small compressor, the gas being drawn from the town main by means of a non-return valve. The pressure required is 25 lb. per sq. in.

The fuel gas, the oxygen, and compressed air at 35-50 lb. per sq. in. are fed into the pistol by rubber tubes and are all controlled by a single valve in the pistol case. The gas and oxygen pass through pipes in the pistol-case to a mixing chamber. Part of the air, controlled by a screw valve, is used to drive a small turbine actuating two small rollers which feed the wire steadily to the inner nozzle, where combustion of the gas and melting of the metal take place. The rate at which the wire is fed is determined by the metal used, and melting takes place evenly and uniformly. Around the blowpipe flame is an annular nozzle through which the compressed air is fed. This air in contact with the hot expanding gases of the flame

causes a high pressure to be developed at the melting focus, which forces the molten metal forward as a fine spray. The air absorbs and dissipates the heat generated by the flame, so that at spraying distance, about 5 in., the spray is only slightly warm. Inflammable articles and goods which are liable to be damaged by high temperatures may therefore be sprayed with safety.

As regards the choice of combustible gas, in most cases town's gas is much the cheapest. The accompanying table shows the cost of spraying various metals using town's gas, compared with the cost of using hydrogen. The price of town's gas is taken at 3s. 6d. per 1,000 cub. ft. to cover the cost of compression (calorific value 450 B.Th.U. per cub. ft.).

The cost of hydrogen is taken as 52s. 6d. per 1,000 cub. ft., and that of oxygen 27s. 6d. per 1,000 cub. ft. In the total cost is included 1s. 1½d. per hour for labour and 2d. per hour for compressed air.

Metal.	Metal Sprayed Lb. per Hour.	Cost, Pence per Hour.	Town's Gas.		Oxygen.		Total Cost.	
			Cub. Ft. per Hour.	Cost per Hour.	Cub. Ft. per Hour.	Cost per Hour.	Per Hour.	Per Lb. Sprayed
Tin........	9·8	245	61	2·5	37	12·0	275·0	28·05
Lead	17·5	140	61	2·5	37	12·0	170·0	9·71
Zinc	4·8	43	69	3·0	41	13·5	53·5	15·63
Aluminium	1·2	21	69	3·0	43	14·0	53·5	46·52
Nickel	1·4	62	69	3·0	44	14·5	95·0	68·0

Metal.	Metal Sprayed, Lb. per Hour.	Cost, Pence per Hour.	Hydrogen.		Oxygen.		Total Cost.	
			Cub. Ft. per Hour.	Cost per Hour.	Cub. Ft. per Hour.	Cost per Hour.	Per Hour.	Per Lb. Sprayed.
Tin........	11·4	285	38	24·0	11	3·5	328·0	28·77
Lead	18·4	147	58	36·5	19	6·5	205·5	11·16
Zinc	5·5	49·5	72	45·5	25	8·5	114·0	21·6
Aluminium	1·2	23	74	47·0	26	8·5	94·0	78·3
Nickel	1·8	79	90	57·0	32	10·5	162·0	90·0

In April, 1933, there were 145 pistols in use in this country employing town's gas, with an average hourly consumption of 69–70 cub. ft. Assuming these pistols to be worked 8 hours a day and 300 days a year, the total gas consumption for metal spraying would be 24·4 million cub. ft. annually.

Sherardising.

Rustproofing by the process known as sherardising makes use of the fact that when iron or steel is heated to certain temperatures in zinc dust, an iron/zinc alloy is formed on the surface of the metal. The process may be compared with the case-hardening of steel, zinc dust, however, being used in place of carbon. In the use of zinc dust sherardising differs from all other methods of application of a zinc coating, most of which use the zinc in the form of spelter. The zinc dust is produced by distillation of zinc, and must be of a very high quality, since although low grade dust can produce an apparently good coating, on exposure this will deteriorate far too soon.

It is important that the articles to be treated should be thoroughly clean, since sherardising will not bridge impurities. The protective coating is an alloy, and therefore the resistance to corrosion depends as much on the physical condition of the metal treated as on the zinc dust. Cleaning of mild steel and wrought iron is effected by pickling and neutralising, and that of malleable iron and grey iron by sand or shot blasting. When acid pickling is used care must be taken to ensure that all traces of the acid are removed, since otherwise the sherardised surface may be locally dissolved away on exposure to damp atmospheres.

After cleaning, the articles are packed into steel containers together with the requisite quantity of zinc dust mixed with sand, and the container is placed in a furnace. While the container is in the furnace it is rotated to ensure the even distribution of the zinc dust over the surface of the articles treated. The success of the operation depends upon accurate pyrometric control, and the time of treatment is determined by the specification to which the articles have to be treated. The actual process of sherardising will be best described by an account of the methods used by the Zinc Alloy Rustproofing Co., of Wolverhampton.

The company makes its own furnaces owing to the specialised problems involved. The two largest are about 15 ft. long, and are heated by a double row of gas jets fed from a central pipe. The drums in which the articles to be sherardised are placed are of square cross-section, and can be removed for filling and emptying. They have circumferential flanges, which rest on small wheels, giving a friction drive and providing for rotation of the drum. The plate at the end of the drum is sealed on with asbestos cement in order to minimise leakage of zinc dust from these ends. The temperature is read by means of a pyrometer inserted in one end.

The drums take about one and a half hours to attain the requisite temperature of 750° F., and this temperature is maintained for about three quarters of an hour to an hour. In some cases it is necessary to preserve the temper of the material to be treated by heating it at a temperature below 700° F., in which case the time of treatment may be as much as doubled.

The two 15-ft. furnaces consume about 900 cub. ft. of town's gas per hour. The company also has two 6-ft. brick furnaces which consume about 800 cub. ft. per hour, and there are eleven small furnaces, six 24 in. long and five 16 in. long, heated by a single-bar burner beneath the centre of the drum. The 24-in. furnaces consume 230 cub. ft. per hour, and the 16-in. ones 180 cub. ft. per hour.

The gas consumption is calculated per cubic foot of sherardising drum space, and the costs are estimated on the same basis. For the year 1931 the average gas consumption was 234 cub. ft., and the weight of parts treated was 0·66 cwt., both per cub. ft. of sherardising drum space.

The larger drums require individual handling by travelling crane for filling, placing in and removal from the furnaces. The smaller drums are handled by means of a roller track. When the parts to be sherardised have been placed in the drum, the latter is filled from an overhead hopper with a mixture of zinc dust and sand in the correct proportions. It is then hooked on the conveyer and pushed over to the furnace, where one end engages in a rotating clutch. When the treatment is completed the drums are removed from the furnace and taken by means of the same conveyer to a bench opposite, where they are sprayed with water to cool them down. They are next opened, and the parts are separated from the sand and zinc by means of sieves. One of the parts is taken from each drum, and if the coating is found to be satisfactory, the remaining contents of the drum will be up to the same standard. The mixture of sand and zinc dust remaining is next sieved to separate the coarse-grained sand from the very fine zinc dust. Both sand and zinc dust are then returned to overhead hoppers to be used again. About a quarter of the zinc dust put into each charge is actually used in forming the protective coating. The weights of the component parts of each charge are very carefully calculated to give a certain percentage of new zinc dust, a certain percentage of old zinc dust, and a certain percentage of sand.

The finished product has a uniform zinc impregnation over the whole surface. In this connection it is important to note that sherardising does not merely produce an independent coating of zinc, as in the case of metal spraying without subsequent heat-treatment, but a zinc-iron alloy with the surface of the metal. This coating can therefore only be removed by chemical or mechanical action sufficiently severe to remove also some of the base metal. Moreover, in contrast to electro or hot dip galvanising, the thickness of the coating is uniform whatever the shape of the articles treated. The dimensional increase in most parts at present processed by this method is not more than 0·001 in., and this amount of clearance is generally allowed in standard machining tolerances. If desired, by increasing the time of treatment, an additional coating of

zinc may be deposited on the zinc-impregnated surface, or alternatively, the sherardised surface may be used as a base for various finishes, such as lacquers, paints, or an oil-black finish known as Sherablak.

The size of articles which can be treated is, of course, limited by the capacities of the containers. The more compact the material, the cheaper it is to treat, and therefore many articles are sherardised at an intermediate stage of manufacture—that is, after all the machining has been done, but before the final assembly.

The cheaper forms of brass, which form a heavy coat of verdigris on exposure to acids, may be sherardised with beneficial results. In this connection the process has been used with considerable success for the brass terminal connections of electric batteries. Sherardised brass, however, should not be exposed to alkalis.

Recent developments of the process have made it possible to produce chromium, copper, or aluminium coatings. In chrome sherardising, the iron zinc alloy is first formed ; this is then given a high polish and is chromium-plated. Copper sherardising gives the appearance of solid copper. Articles so treated can be polished or left with a dull matt finish. Articles sherardised with aluminium will withstand high temperatures without scaling. The process has to be carried out at a much higher temperature, and is therefore more expensive, but it is especially suitable for pyrometer stems and iron and steel fittings for furnaces.

Parker Process.

The Parker process of rustproofing achieves its object by converting the surfaces of iron and steel articles into phosphates, which are insoluble in water and permanent in air. This chemical treatment of iron and steel presented great difficulties until it was discovered that such insoluble phosphates are formed on the surfaces of iron and steel immersed in a bath containing a dihydrogen ortho-phosphate, some free phosphoric acid and some ferrous monohydrogen phosphate. Metals which have been found to give suitable dihydrogen orthophosphates are iron, zinc, manganese and cadmium : and of these a mixture of the iron and manganese salts gives the best protective covering. When these two salts are used in the bath, the protective coating consists of both ferrous and manganese phosphates, and in order to give the maximum rust protection the ratio of iron to manganese in the coating should be 1 : 1. In order to obtain this, it has been found that the ratio of iron to manganese in the bath must be 2 : 1, since selective deposition appears to take place. As the treatment proceeds, iron is actually dissolved out of the articles treated, so that the concentration of iron in the solution increases, necessitating the addition of manganese dihydrogen orthophosphate at intervals. In practice this is done when the manganese-iron ratio falls to 1 : 3. The presence of copper in the metal phosphate coatings has been found to increase the resistance to corrosion, and this is generally effected by suitable additions to the treatment bath. A more recent method, however, is the treatment of the Parkerised surface with copper ferricyanide solution. The objects to be treated are steeped at a temperature near the boiling point in the solution, which contains also 2% of the alkali ferricyanide.

The process is controlled in this country by the Pyrene Co., Ltd., of Brentford, Middlesex, who supply the necessary salts under the name of the Parco rustproofing powder. To prepare the bath, the recommended quantity of this powder is dissolved in boiling water. The articles to be rustproofed are then placed in a suitable cradle and lowered into the bath, where they remain for about sixty minutes.

Most large plants in this country are steam-heated, but there is a considerable number of gas-heated installations. It is difficult to give exact figures for gas consumption, as the plants vary considerably in size to suit individual requirements. The operating temperature of the bath is 210° F., so that it would require about 800 cub. ft. of gas to heat a bath of 200 gals. from 110°F to which temperature it may be expected to cool during the night (assuming 50%

efficiency). A further supply of gas is, of course, required to maintain this temperature during working.

Articles treated by the Parker process do not require any further finishing, but there is a similar process known as Bonderising for rustproofing articles before the application of paint, lacquer, or enamel. The time of treatment is much less in this case, being only about 10 mins. It is the last few minutes which produce adherence, as the coating may be wiped off if treatment is stopped after 6–8 mins. Bonderising produces a crystalline coating which absorbs the enamel or lacquer into the spaces between the crystals, thus producing a permanent cohesion between the metal and the enamel. Neither the Parkerised nor the Bonderised coating has a very great abrasion resistance, but where a chip occurs rusting is confined to the exposed metal, and will not spread, as is the case when enamel is applied to an untreated surface. For this reason, Bonderising has found many applications in the motor industry.

There is an interesting installation at the Long Beach, California, works of the Ford Motor Co., who use this method of rustproofing motor parts before applying the enamel. The plant occupies a space 32 ft. wide and 136 ft. long, and consists of a washing chamber, a rustproofing tank, and a drying furnace. The parts are handled throughout by a continuous conveyer, and are washed by pressure sprays situated in three tanks, of which the first two contain soda solution and the third fresh water. They next pass to the rustproofing tank, which is maintained at 210° F. by means of steam raised in gas-fired boilers. The parts pass through the tank three times, the total time of immersion being 10 mins. The final operation is that of drying, which takes place in an indirect ga -fired oven. This is heated by four gas burners situated below the oven, and a temperature of 450–500° F. is maintained automatically. After drying, the parts are conveyed to the enamelling portion of the works.

The enamelling plant consists of two dip tanks and two ovens, the whole being situated in a glassed-in enclosure to prevent the penetration of dirt-laden air. All air used in the system is first passed through air filters. The enamelling ovens are 143 ft. in length, and are heated by eight gas burners situated below the oven. The products of combustion of the gas burners are passed through a series of tubes, round the outside of which is circulated air, before being fed into the ovens. The ovens are equipped with recording pyrometers, and the temperature is automatically controlled by means of a valve in the gas supply, which is kept open against a spring by means of the pressure on a diaphragm. When the oven becomes too hot, a thermostatic valve comes into operation, which causes the pressure on the diaphragm to drop, thus closing the gas supply valve until the temperature in the oven has fallen to the correct value. Both coats of enamel are baked on at an initial temperature of 250° F. and a final temperature of 440° F.

Coslettising.

The Coslett process of rustproofing consists in the immersion of the articles to be treated in a solution of zinc phosphate with or without the addition of boric acid. The parts to be treated are first cleaned, and any adhering grease removed, after which they are lowered into a tank containing the rustproofing solution maintained at its boiling point. The time of treatment depends to some extent on the nature of the articles treated, and the physical condition of the surfaces, but varies from 1–2 hours, when zinc phosphate is used alone, to as little as a quarter of an hour, when boric acid is also present. After treatment, the parts are washed in a second tank, and are then transferred to a drying oven.

The necessary plant consists of a pair of tanks and a drying oven. Two more tanks are required if degreasing is carried out by means of a caustic solution, one for the latter and one for water ; but the present tendency is towards the use of an I.C.I. degreaser, such as has already been described. In the case of " batch " installations, the parts are usually loaded on racks, which can be lifted and

transferred from tank to tank by means of a pulley-tackle ; or alternatively, small parts are placed in perforated drums. The process can, however, be adapted to use in a modern mass production works operating on the conveyer system. In such cases a continuous conveyer drying oven is the best method of working. Such an oven is very similar to the type used in many enamelling plants, except that there is a gap between the boiling water wash tank and the drying chamber, in order to prevent excessive steam from entering the latter, and to allow some of the water to drip off the parts. The temperature of the drying oven is maintained between 200° and 300° F., and the drying time is 15–30 mins., much less than in the case of an enamelling oven.

Heating of the tanks can be done by almost any fuel. In large works, where steam is constantly available and there is a big through-put, it may pay to heat the tanks by means of steam coils, but in general gas burners form the most convenient and economical method, and about two-thirds of the Coslettising installations are gas-heated. The gas consumption varies according to the method of operation, but a 500-gal. tank takes about 2,000 cub. ft. for heating up from 110° F., the temperature to which it may be expected to cool during the night, to boiling, and about 200 cub. ft. per hour for maintaining, so that working eight hours per day (excluding heating-up) with one such Coslettising tank and one wash tank, the gas consumption is 2,500–3,000 cub. ft. A further quantity of gas is used for heating the degreaser or caustic tank, and also the drying oven, so that the total annual consumption is quite considerable and enables the firm to take advantage of the special rebates offered by most gas undertakings to large industrial customers. Nevertheless, the throughput, particularly when boric acid is used in the tank, is very high, and 20–30 cwts. of small parts may be treated per 100 gals. of tank capacity per day.

The zinc phosphate required for the process is prepared by dissolving granulated zinc in hot 50% phosphoric acid, in the proportion of about 4½ lb. of zinc per gallon of 50% acid. After allowing the solution to stand, and stirring well, a white pasty mass is obtained, which can be kept in a wooden tub and used for making up the solution in the process tanks. A typical bath contains 2 oz. of this acid zinc phosphate paste, and 1½ oz. of boric acid per gallon of water.

The presence of the boric acid speeds up the reaction, and further advantages are that the process solution remains clear, and a much more even deposit is obtained without any trace of patchiness. Moreover, whereas when zinc phosphate alone is used the articles which have been treated have to be rubbed over before enamelling in order to remove surplus deposit, which clings to the surface as a fine grey powder, when boric acid is used, such rubbing is not usually necessary.

Various kinds of finish can be applied to Coslettised articles, a matt black finish can be obtained by oiling, and a lustrous finish by application of a carbon compound and subsequent stoving. Probably, however, the majority of the parts which are rustproofed in this way are subsequently enamelled, giving a very fine and durable surface. The motor-cycle and cycle industries in particular have found the process of the greatest value. There is, for instance, a continuous Coslettising plant installed at the Birmingham works of New Hudson, Ltd. The parts are handled by a continuous conveyer, the time taken for the complete circuit being 46 mins., of which 20 mins. are taken up in drying. The capacity of the Coslettising tank is 2,000 gals. This is followed by a boiling water tank with a capacity of 1,000 gals., both tanks being gas-heated. When starting up, the gas consumption is 5,900 cub. ft. per hour, but this falls considerably once the working temperature has been attained.

Other Processes.

The Follsain process is claimed to be applicable to all ferrous metals and alloys. It consists in the impregnation of the surface by means of the penetration of metallic chlorides into the base metal by diffusion. The method of treatment is similar to case-hardening, and is carried out in furnaces, which are, in general, fired by pulverised fuel or oil burners, and there has, as yet, been no application of town's gas to this process. Articles treated can resist oxidation at high temperatures and also the corrosive attack of acids, such as nitric acid, hydrochloric acid, and salt water.

An interesting application of the process makes use of aluminium. The ferrous material is packed with a mixture of powdered aluminium, chromium chloride, and a catalyst in a metallic container. When this is heated at a temperature of 1,000° C. for three or four hours, an alumino-thermic reaction takes place, giving the objects treated a lightly adhering skin of alumina beneath which is a skin of metallic aluminium, and finally, the surface of the metallic object has been impregnated with chromium metal. The result is highly resistant to oxidation at high temperatures and to acids.

In a process used by the Rustproofing Co. of Canada, articles are loaded in baskets and immersed for 1–5 mins. in a tank containing a hot alkaline solution. They are then given a warm water rinse, and are finally transferred to a dip of slightly acid reaction. The articles need no preliminary cleaning, and the result is a matt black finish which forms a good base for paint. A gloss may be obtained by an oil dip.

The Forest Products Laboratory at Madison, Wisconsin, has found that by subjecting nails to the action of a 2% solution of ferric chloride in water, in the presence of mercuric chloride or the salts of other metals, a good coating of rust can be produced. On removal from the solution the materials are allowed to dry in a warm atmosphere and are then exposed to a temperature of 100° C. and a relative humidity of 80%, and finally they are immersed in water. The artificial coating of rust is thus fixed and prevents further oxidation.

Another method of rustproofing which has been developed recently makes use of a synthetic drying oil known as S.D.O. It is an amber-coloured viscous liquid, and is applied to the surface to be treated as a solution in naphtha. After the evaporation of the naphtha the S.D.O. is converted by spontaneous polymerisation to a hard, brilliant film of golden oak colour. It is ready for ordinary use in 24 hours, but for use under very severe conditions a period of four days to a week should be allowed. The polymerisation may be accelerated by the action of heat. The completely polymerised film has a very high resistance to acids, and is only attacked by such strong oxidising agents as nitric and chromic acids or sulphuric acid over 50%. Steel panels treated with S.D.O. have been under sea-water for two years without corrosion, and others exposed to atmospheric conditions have remained unaffected for even longer periods. The material is expensive, and has therefore not come into general use, but where severe corrosion or chemical attack has to be resisted the S.D.O. film has been found of the greatest value.

The growth of the mass-produced small car industry, and also of aeronautical construction, has greatly increased the importance of rustproofing. From the account given of the more important processes now in use it will be seen that town's gas can assist materially in this industry. Owing to the ease with which this fuel can be controlled it is eminently suited to all immersion processes, such as the Parker and Coslett processes, where the maintenance of an exact temperature is necessary for efficient and economical working. In the case of large installations, where cheap steam is available, heating by steam coils is probably the most economic method ; but the examples of gas-heated installations already described show that this fuel has many applications in the industry. As the amount of work to be treated increases the economic advantage to companies using rustproofing processes of the use of town's gas will be still further increased, since an expansion of work will enable them to avail themselves further of the reduced rates offered by gas undertakings to large industrial consumers.

Controlling Hardening Operations

The vital factors necessary to efficient hardening practice are heating, quenching and furnace atmosphere, and much development has been made towards complete control of these factors. In this article the recent " Vapocarb Hump " method of hardening is described.

IT has been said that the results sought in heat-treatment practice are determined by the proper combination of the man, the furnace and the steel—not by any one or two of them. Good steel is entitled to proper treatment by good men, and both are entitled to the use of a good furnace to produce better results. But many factors affect the selection of heat-treating equipment and hundreds of different designs of fuel and electric furnaces have been developed to meet the wide range of requirements in heat-treatment work. During recent years considerable development has been made in controllong the heating, cooling, and handling of parts required to be heat-treated, and more recently attention has been given to the furnace atmosphere ; the object being to control each operation and leave as little as possible to the human element.

One of the methods developed for the heat-treatment of steel is the Hump method, the equipment for which consists primarily of a vertical furnace wound with resistance wire, and a very sensitive thermocouple, which is inserted through the bottom of the furnace so that the hot junction of the couple is near to the centre of the work. In addition, the equipment is provided with an automatic temperature recorder which draws a temperature curve on a chart. The curve drawn by the recording instrument shows the temperature and time at which the charge reaches its critical change point, and produces an indication in the form of a hump in the curve. Quenching is done at a predetermined interval after the hump appears, so that it, and all subsequent operations, depend upon accurate knowledge regarding the proper interval between the critical point and the quench. This brings the control of the quench definitely in the hands of the operator.

An improvement subsequently embodied in this equipment provided a means for accurately controlling the rate of heating, in addition to control of quenching or soaking point. For this purpose a combined recorder and recording controller was used in the equipment, instead of a single point temperature recorder. This instrument draws two curves on the chart ; one showing the temperature of the work, and the other the temperature of the furnace, the difference between these two temperatures being controlled automatically, in order to prevent the building up of an excess temperature difference between the work and the furnace, at any point in the heating cycle. The importance of this improvement is readily appreciated because automatic control of the rate of heating, as applied in the Hump furnace, ensures uniform heating of all sections of each steel part up to the critical change-point, through the critical change-point, and on up to the quench point, together. Its effect in eliminating breakages in hardening and in rendering distortion practically negligible was quickly realised. Actually the difference controller holds the temperature-difference constant during the critical period, and prevents the strong tendency to overheat at this period when the temperature difference between the steel and the furnace increases rapidly. This function is performed automatically, and as will be noted on the accompanying diagram control is particularly active during the critical changes.

A more recent development, " Vapocarb " atmosphere control, has now been applied with the Hump method of hardening, known as the " Vapocarb Hump Method," which brings under complete control the three vital factors on which correct hardening depends : first, the rate of heating ; then the cooling or quenching point ; and, finally, the furnace atmosphere. This new development protects
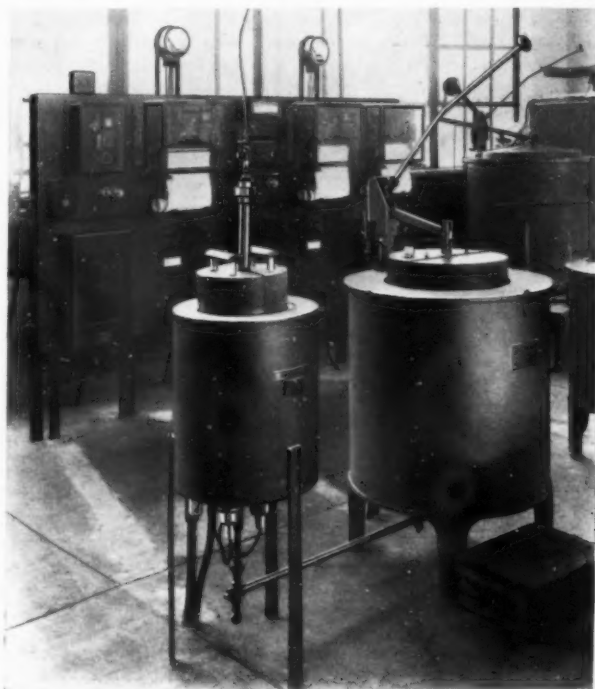

Vapocarb Hump installation, including cracking unit, hardening furnace and automatic control equipment.

the surfaces of parts treated, and renders protective pack hardening and protective coating of tool steels no longer necessary. The Vapocarb atmosphere in the furnace protects the carbon in the surface of the steel, and gives maximum efficiency from the quench, because the parts coming from the furnace are clean. This method is claimed to ensure maximum grain refinement for a given depth of hardness. It is only necessary to clean off the quench stain and the surface is as smooth as when it entered the furnace.

In order to effect this improvement, a small cracking unit, for creating a reducing atmosphere in the hardening chamber, forms part of the equipment. Into this cracking unit a special fluid drops from a container suspended above it. A connecting pipe conveys the cracked gas to the working chamber, and the burning stream of exhaust gas is visible at the port in the lid, when the equipment is in operation. The fluid drops at a controlled rate, usually 1 to 3 drops per second, into the cracking unit, which is automatically maintained at a constant temperature between 1,450° and 1,500° F., where it gasifies and cracks. The gas then passes through the connecting pipe and enters the gas-tight retort of the Hump furnace where it replaces the air. This gives a slightly carburising atmosphere, which naturally cannot act as a carburiser at normal hardening temperatures with normal tool steels, but which gives positive protection to the carbon in the surface of the steel. Both the furnace and the cracking unit are electrically heated, while the automatic temperature-difference controller and the recording controller are electrically operated.

In operation this equipment has two thermocouples mounted in the Hump furnace—one for the temperature

of the work and the other for the temperature of the furnace. The recorder is actually a combination recorder and recording controller, which draws two dotted lines on the chart. One dotted line shows the temperature of the work. This is the Hump chart, which shows the rate of heating and time cycle of the work itself, signals the critical change point and records the quench. The other dotted line shows the difference between the temperature of the work and that of the furnace.
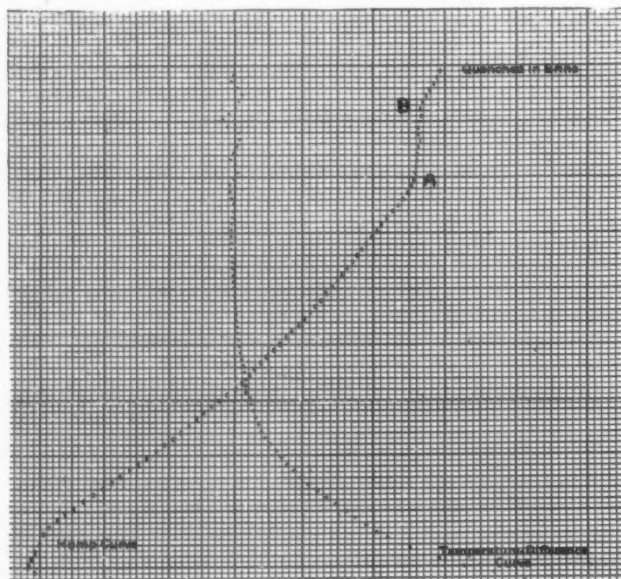
A sample record of automatic control of rate of heating used in hardening punch of 1·0% carbon steel. The control curve represents temperature difference between furnace and work, while the hump curve represents approximate temperature of the work. Note the activity in the difference curves as the controller held the heat input below normal in the critical.

This difference in temperature between furnace and work is automatically held constant, at whatever value the hardener sets on the control dial, by operating relays to increase or decrease the heat input as required. The operator simply sets the control for the number of degrees of temperature difference which will give the desired rate of heating, and heating of the work is maintained up to the critical change point through the critical change point and on up to the quench point automatically, without further thought on his part.

By simply throwing a switch the instrument may be taken off temperature difference control and put on straight temperature control. After the work has passed the critical change point, if it is to be soaked, the hardener switches to temperature control and sets the control dial for the desired soaking temperature. The work is heated up to that point and then soaks without further rise in temperature until taken out for quenching.

The entire operation of heating is carried out in a slightly carburising atmosphere which preserves the surface of the steel parts being hardened; thus there is practically no refinishing after treatment. The whole equipment gives the hardener absolute control, and it is claimed that the average life of tools and dies hardened by this method effects substantial savings in uninterrupted production. The method enables the hardener to approach the ideal structure and surface characteristics in the hardening of a steel part and to harden the average part as well as he hardens the best. An accurate record of the heating of each part is provided, and when the correct treatment for a tool or a die has been determined it can be repeated at will by duplicating its chart record.

The method provides complete control of the vital hardening factors and permits analysis and progressive

improvement of hardening technique, which are direct savings in tool and die costs. It has been developed by Leeds and Northrup Co., and further information regarding its application to hardening operations may be obtained from The Integra Co., Ltd., 183, Broad Street, Birmingham.

Casting Motor-car Crankshafts.

THE use of forged steel shafts has been the orthodox practice for motor-cars since the inception of this form of transport vehicle, and it is of interest to note that the Ford Motor Co. has initiated a practice of a revolutionary character by developing the cast alloy crankshaft. This development is being applied to the 1934 V-8, according to Dwyer;[*] it is the outcome of intermittent experimental effort over the past five years, at the River Rouge works, and it is believed that the cast crankshafts now being used are superior in every respect to the forged steel shafts formerly placed in Ford engines. Before the present crankshaft was placed on production basis, and fed as a routine product into the assembly line, approximately 2,000 crankshafts had been placed in cars where their behaviour could be checked closely. These were installed in service cars and other vehicles operated by the Ford company. The majority of these crankshafts have been in constant service for at least two years, while others have been in use for varying periods up to five years. None has failed in service due to distortion or appreciable wear, and none has shown defect of fibre stress or crystallisation usually associated with ferrous metal subjected to constant revolution and vibration, and known as fatigue of metal.

Composition and subsequent heat treatment of the casting apparently renders it immune, at least within practical operating limits, to the fatigue factor which materially lowers the life expectancy of a forged steel shaft. Long life of the cast shaft is ascribed to the comparatively high carbon as well as its alloy content (approximately 1.35% carbon), and to form and distribution of the carbon throughout the mass. The carbon also to some extent provides some lubrication.

Metal in the crankshaft partakes somewhat of the characteristics of steel, of gray iron and malleable iron and therefore cannot be classified under any of these headings. For the same reason the carbon evades any exact classification, but some exists in a state comparable to the temper carbon in malleable iron. It is understood that the material has been classified as a "high-carbon alloy steel."

As cast, the crankshafts resemble malleable iron at the same stage, in that the metal is white, brittle and easily broken. A comparatively simple heat treatment transforms the metal into a material that is almost impossible to break. The castings are placed in a furnace and raised to a temperature of 1,450° F. and allowed to soak for an hour. They are removed from this furnace and air cooled to a temperature of 800° F., then placed in a second furnace where the first treatment is repeated. Upon removal from the second furnace, they are air cooled rapidly to 800°, then allowed to cool slowly to atmospheric temperature.

Brinell hardness of the heat-treated castings averages 302, as compared with 200 for forged shafts before and 444 after machining and hardening. However, the hardness of the cast shaft is uniform throughout, while the forged shaft presents varying degrees of hardness from the outside to the centre. It is claimed that this is one factor which is partly responsible for the marked superiority of the cast shaft over the forged shaft in resistance to torsional stress and evidence of fatigue.

In addition to other desirable features the cast crankshaft is considerably lighter than the forged steel shaft. This is due to certain features in design entirely feasible in the foundry, but outside the scope of practical accomplishment in the forge. The cast shaft weighs 65 lb. rough and 56 lb. finished, as compared with 90 lb. in the rough forging and 66 lb. finished.

* Dwyer, *Steel*, Vol. 94, No. 12, pp. 25-27.

Metal Finishes used in Modern Architecture

By S. Wernick, M.Sc., Ph.D.

The durability and general efficiency of a structure may depend upon the finish which that structure receives, and in a lecture on the above subject, delivered at The Building Centre, recently, and from which the following is extracted, the author discussed the basic principles underlying metal finishing and the value of various finishes.

THE advent of scientific methods, during the last fifteen years or so, has rationalised metal finishing, and most of the processes are now rigidly controlled with close co-operation between the laboratory and the shop throughout all the stages in the process. Apart from this fact, the science and art of metal finishing is to-day very highly specialised, and even the specialist finds that it takes the whole of his time to keep abreast with recent technical developments which are occurring in various parts of the world.

Metal finishing is confined to the treatment of metal surfaces, the object usually being to effect a change, by means of a superficial covering, in the appearance of the surface. Modern methods of metal finishing have been developed largely during the past century. The art of bronzing, for instance, was developed in France just prior to 1828, by which year only one colour of bronze was known to the trade. This was known as Verde Antique, different shades of which were obtained according to the customer's taste. Florentine bronze appeared in this year, and was quickly followed by other methods of bronzing, some of them even to-day being recognised as the finest finishes in the art, produced only upon the most expensive bronzes. The rise of electro-plating can be said to have commenced some seventy-odd years ago, the first metals to be electro-deposited on a commercial scale being silver, gold, nickel, and copper. To-day, in addition, the metals zinc, tin, brass, chromium, cadmium, platinum, palladium, rhodium, and an extensive range of alloys are electro-deposited commercially for various purposes.

Whatever the appearance of the finish, its serviceability depends upon a few basic properties which it should possess. It must adhere tenaciously to the base metal, for instance, and resist strongly any attempt to detach it. The best type of bond between the finish and the base material is a chemical one, such as obtains with many types of electro-deposits, and in certain other cases, such as galvanising, where an alloy phase exists between the base metal and the coating. Such a deposit possesses truly remarkable powers of adhesion. Thus, it is possible to obtain nickel-plating on steel, which is so tenacious that in any attempt to part the deposit forcibly by applying very high tension the base metal will part from itself rather than at the juncture of base metal and deposit. A second form of adhesion, which is only inferior to a chemical bond, is one of a mechanical nature. This occurs when the finish is interlocked between the interstices at the metal surface. To achieve this the surface may be roughened by chemical etching, or by sand-blasting, or other suitable means. Porosity of the finish is another important factor, since one that is highly porous acts as a sieve, and under certain conditions may be worse in its protective capacity than no finish at all, because it may result in intensification of corrosion at the pores. Uniformity over a surface is another essential property of a metal finish, while adequate thickness of coating and its ability to withstand reasonable wear and tear in service are others.

The use of the ferrous metals for structural purposes is greater than the use of non-ferrous metals in point of quantity, but they suffer from the great disadvantage that they are readily corroded by the atmosphere, both appearance and strength steadily deteriorating as a consequence, and they must be protected by one of the many finishing processes which are available. The processes employed are constantly increasing in number, although, basically, there are two main classes of coating processes—namely, the inorganic coatings, comprising metals and inorganic compounds, and the organic coats, which include paints, enamels, varnishes, and lacquers. In the first of these classes the number of compound finishes is small in comparison with the metal finishes available. They include the phosphate-type coatings used as a basis for enamels, etc.

Interest in the application of metallic coatings for rust prevention was very much quickened by the war, and as a result numerous methods of applying such protective coatings have been developed and exploited industrially within the last few years.

The principal methods are hot dipping, electro-deposition, vaporisation or cementation, spraying, chemical replacement, and rolling. Of these the first four methods are the most important.

Chemical replacement consists in the immersion of the metal in a suitable solution of a chemical reagent, containing an electro-positive metal, there being a chemical interchange between the latter and the immersed metal, which receives a coating of the metal in the solution; this coating is necessarily very thin, since the replacement ceases as soon as the initial layer of the coating is produced, and therefore its protective value is usually poor. Rolling, on the other hand, is an old process used to produce a thin coat of the more precious metals on a baser metal, and is not ordinarily applicable to cheap ferrous metals, even though the rolling of such common metals as nickel on base metals has been successfully achieved.

The hot-dipping method which, as applied to zinc, was known as long ago as 1741, is in very common use; tinned iron, too, is widely used. The process, however, owing to the electro-positive nature of tin, does not result in true rust prevention. While the galvanised coat provides excellent protection, it is probably the cheapest, though not the best means of applying zinc to a ferrous surface. It owes its efficiency as a rust preventive to the thickness of the coating, which does not lend itself to ready control, and is of the order of from two to four thousandths of an inch in thickness. The coating forms a true alloy with the iron surface, and a certain amount of the latter finds its way into the molten bath. The coating is, therefore, of necessity not one of pure zinc, such as is produced by electro-deposition.

Electro-deposition.

Electro-deposited coatings, owing to the nature of the process, are by far the purest coatings produced. In the case of zinc and cadmium coatings, for instance, the anodes are of high-grade purity, and the electrolyte contains the pure salt of the metal to be deposited, thus the deposit consists practically of 100% pure metal. The deposit is "grown" at a uniform rate, therefore the process is readily amenable to control, and almost any

thickness of deposit is obtainable. An adequate thickness of deposit capable of providing very efficient protection is much smaller than with other processes, amounting to 0.0005 in. in the case of zinc plating and 0.0003 in. in the case of cadmium. The process has been developed in recent years so that it may be worked entirely automatically, the whole sequence of cleaning and preparing the metal, plating, washing, and drying being accomplished by a mechanical conveyer system in the course of a surprisingly short space of time.

The " vaporisation," or cementation, process, which has enjoyed increasing application in recent years, consists essentially in heating the articles to be treated while surrounded by the coating metal (which is usually in the powdered form) to a temperature which is not far below the melting point of the latter. As a result, vaporisation of the more fusible metal occurs, depositing upon the surface being treated and forming a closely adhering coating which consists of the alloy of the two metals at the junction, so that the coating becomes an integral part of the surface treated.

There are various applications of this process. The best known is the " Sherardising " process, which employs powdered zinc or a zinc-cadmium alloy, in which the articles are packed in a heated, rotating drum. Aluminium powder is used in the " Calorising " process. The resulting product in this case is highly resistant to oxidation by heat, and is, therefore, used in treating furnace bars, etc. Similarly, the " Chromising " process thermally produces a coating of chromium. Very high temperatures are requisite with these processes.

Spray Process.

The most recently introduced process of all consists in the direct spraying of the coating in the form of the molten metal on to the surface being treated. A special " pistol " is used wherein the metal is fed as a ribbon or wire, and the latter is ingeniously " atomised " by an ignited gaseous mixture of either hydrogen or acetylene with oxygen or air, which passes through annular spaces in the pistol, and is projected at high velocity by compressed air. The principal advantage of this method is the ready portability of the comparatively light spraying apparatus ; hence, the method is used widely for coating outdoor structures, such as bridges, tanks, tunnels, and ships *in situ*, where other methods would be out of the question. Practically all metals may be sprayed regardless of the melting point. Pure coatings can be applied, but owing to the high temperature used are subject to oxidation.

Non-ferrous metals usually are not so readily corrodible as iron, and so the protective aspect is not quite so important. Thus, for example, a nickel deposit on steel should be specified to be at least one thousandth of an inch thick ; on brass or copper it need not be more than half this thickness or even slightly less.

In view of the lightness and excellent structural qualities of many of the alloys of aluminium and their ready working and fabricating properties, their use is extending and new applications are being found for them almost daily. Although a number of these alloys have been produced which are able to stand up to atmospheric corroding influences remarkably well, really effective corrosion resistance can only be obtained by the application of an adequate finish. While aluminium may be successfully plated with other metals under very careful conditions, and it may also be enamelled or lacquered, such finishes in general are not found to be greatly corrosion resistant. It is difficult, owing to the ready oxidation of aluminium in the atmosphere, to provide a coating which will not strip or peel from the surface in due course, owing to the poor adhesion usually achieved.

The most successful methods of protecting aluminium and its alloys utilises the principle that it is the existence of the thin oxide layer on the surface which prevents aluminium from being one of the most corrodible metals extant. I refer to recent electrolytic processes which thicken this natural oxide layer. Such processes may be purely chemical as well as electrolytic, but the type of coat obtained cannot be thickened by purely chemical means to any great extent.

The anodic processes, as the electrolytic methods are commonly known, utilise a suitable electrolyte in which the article to be treated constitutes the anode of the circuit. As a result a coating of aluminium oxide forms which possesses remarkable properties. Not only does it impart very considerable corrosion resistance to the article treated, but under certain conditions extremely hard coats are produced which are highly abrasion-resisting and, therefore, increase the wear resistance of the article to a very appreciable degree.

The oxide film which has mordanting properties can also be coloured by the use of suitable dyes, and highly pleasing decorative effects may be achieved by these means. The oxide coat, which is integral with the base metal and does not, therefore, strip or peel if correctly applied, is also incidentally electrically insulating.

In the future anodising will be one of the most useful adjuncts to the architect and builder who wishes to make use of aluminium, and neither should be discouraged by a mass of poor work which has appeared on the market during the last two or three years, since it is not really representative of what can be turned out when the process is carried out on scientific lines. As with chromium plating, the reputation of which suffered greatly in the early days because of shoddy production methods, so with anodising. The similarity to chromium also extends to a number of gross overstatements and somewhat ridiculous claims which have been made for anodising recently. The anodised article will *not* resist all acids known to the chemist, and certainly will not stand up to alkali ; nor is every colour produced leech-proof, non-fading, and, generally speaking, everlasting ; but it is possible to produce highly corrosion-resistant coatings and a limited range of reasonably light and heat resisting coloured finishes which are totally adequate at present for the architect and builder.

Casting Albanoid.

ALBANOID is a nickel silver standard composition designed to facilitate the production of reliable nickel silver castings, and is marketed by Henry Wiggin & Co., Ltd. Castings produced from this alloy are uniform in colour and properties because the nickel, copper, and zinc contents are maintained within very close limits. Albanoid melts at 1095° C. and should be poured at 1250° C. to 1400° C. It is essential that melting should be done fairly quickly, and a suitable flux used in order to prevent undue absorption of gases. Melting an 80-lb. heat should not occupy more time than $1\frac{1}{2}$ hours, otherwise the flux will not prevent gas absorption and porous castings will result. The melting pot should be covered during melting and, if possible, the complete charge made at once, because any serious check due to the addition of cold metal may lead to faulty castings. The metal should be covered with a flux, a suitable one consisting of 80% borax and 20% boric acid.

Although Albanoid jackie pigs contain a slight excess of manganese, it is advisable to deoxidise the heat immediately before pouring. The most useful deoxidant for general foundry work is magnesium ; a sufficient quantity being $\frac{1}{2}$ oz. per 80 lb. of metal. It is of the utmost importance, when making this addition, that all the magnesium be pushed under the surface of the molten metal. The correct time to add it is when the charge has melted and is ready for pouring. No time should be lost in pouring the metal into the moulds once the pot has been removed from the furnace, and the metal should be carefully skimmed. The runners should be of ample size as the metal chills very rapidly ; it is a useful rule to make them twice the size of those provided for a similar casting in brass. This is particularly important in the case of small castings as many failures have been due to this cause. An allowance of $\frac{1}{8}$ in. per foot should be made for contraction.

Recent Developments in Tools and Equipment

Cold Roll Mill Drive and Barring Gear

CONSIDERABLE improvements have been made during recent years in the design and construction of mills both for ferrous and non-ferrous metals. These improvements have not only increased the tonnage during a given working time, but have had a considerable influence in reducing the cost of production and maintenance charges, which have resulted in an increased overall efficiency from the plant. In addition to improvements in the design of mills, many advantages have accrued as a result of modifications in the design of mill drives and the application of electric power. The use of totally enclosed reduction gear sets, the selection of improved materials and special attention to lubrication have speeded up production, increased the life of wearing parts, and

barring motor, which is a separate 15 h.p. vertical flange-mounted motor, and provides auxiliary drive for barring through a worm reduction gearbox and through single-purpose steel spur gears to the main driving motor shaft extension.

The worm reduction gearbox is a separate unit made in halves, the motor being mounted on top of the unit. The worm and wormshaft is made in one piece from 3.5% nickel casehardening steel, the worm threads being casehardened and subsequently ground accurately to shape. The wormshaft is mounted at both ends in a double-purpose ball bearing. The worm, which is made of special phosphor-bronze and is centrifugally cast to produce a homogeneous structure free from flaws and defects, is mounted upon a shaft of 40/45 tons steel, which is carried
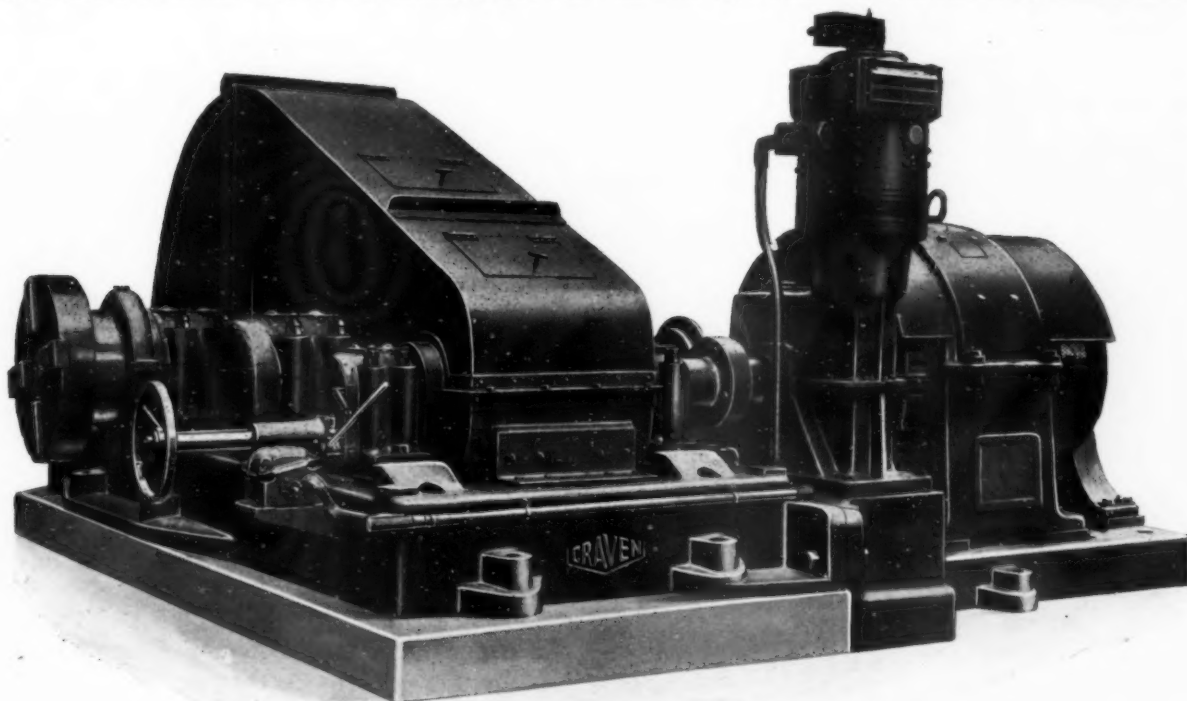
Roll mill drive and barring gear unit ; one of three recently installed in a tinplate works.

generally facilitated production within very small tolerances, which are now required.

An electrical driving unit recently installed in a tinplate works for cold-rolling mills is shown in Fig. 1, which has many outstanding features, and is a noteworthy contribution to rolling-mill developments. The drive shown is designed for driving five mills in line from one 150 h.p. motor. Two similar drives have also been supplied, each for driving four mills in line by a 125 h.p. motor. These three sets were designed and built by Messrs. Craven Bros. (Manchester), Ltd., and are a typical example of the developments being achieved in mill drives.

Each set is equipped with barring gear which is arranged so that it can be used for turning the rolls in position in the mill at a speed of 1½ revolutions per minute. Inch reverse is incorporated in this gear to facilitate the removal of couplings between the rolls, and interlocks are fitted, to avoid incorrect operation, together with automatic stopping of the barring motor immediately the main motor takes the load. Actually the mill is first started by means of the

in ball bearings. The worm-gear runs in an oil-bath and all shafts are efficiently lubricated.

The main drive is through a pair of double helical gears, the pinion being forged steel solid with the shaft, and the wheel consists of a forged steel ring carried on a cast steel centre with powerful flexible coupling from the motor ; the final shaft being fitted with a half-coupling for connecting up to the first of the mills. The gearing is carried on shafts running in self-oiling bearings, the bearings being mounted on a large cast-iron baseplate. With a main motor speed of 375 r.p.m. the gears will reduce the speed to 48 r.p.m. of the final output shaft.

The flexible coupling provided between the output and the pinion shaft and the spur pinion is arranged on a screw so that when the main motor starts up the drive the auxiliary driving pinion automatically slides out of mesh with its wheel, and the 15 h.p. motor is automatically tripped out of action. Both the main motor and auxiliary worm reduction unit are mounted on the same baseplate attached to the main frame.
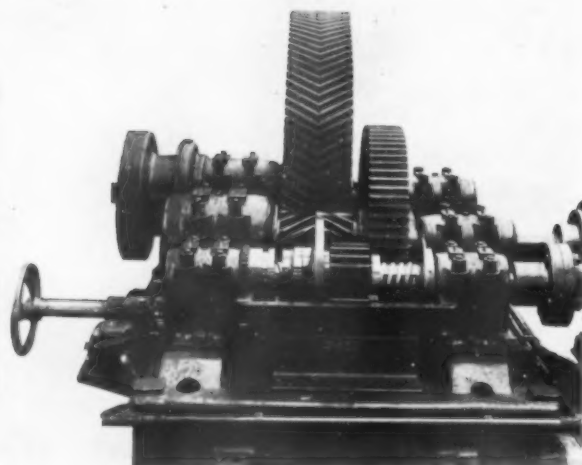
Gearbox cover removed showing arrangements cf reduction gearing.

All the bearings in these units are fitted with gunmetal bushes, and the spur gears are arranged in a solid steel welded oil-tight case so that the gears rotate in an oil-bath. It will be noted, therefore, that every effort has been made to transmit the power to the line of mills so as to ensure a high efficiency in operation. Each unit is complete with safety indicating devices, including lamps, ammeters, and isolating switches.

Water Supply in Trinidad

DURING recent years a great advance has been made in the use of the steel main for towns' water supply, and one of the latest examples is in Trinidad. There is now to be installed by the Trinidad Central Water Supply 39 miles of plain-ended steel pipe of 16 in.-26 in. bore, partly laid alongside the railway. The maximum pressure will be 1,000 ft. head and flexible couplings are also included, the orders having been placed by the Crown Agents for the Colonies. Also the pipes are to be lined with bitumen composition, and wrapped outside with canvas impregnated with bitumen so as to prevent corrosion, while the flexible couplings, after installation, will be coated with bitumen.

It will be interesting to summarise the reasons why steel pipes are used for such conditions, and not cast iron or cement fabric, such as reinforced concrete or asbestos cement. Steel, for example, has a very high tensile strength and is, therefore, ideal for severe conditions such as 1,000 ft. head. Thus, steel pipes can be made to stand almost unlimited pressure, 3,000 ft. head and over as operating in a number of water power plants. Also a steel pipe does not burst and cannot be damaged seriously during transport and laying, representing great advantages as against cast iron, especially when using unskilled and native labour. In addition, a steel pipe, like cast iron, is absolutely non-porous, so that, as with cement fabric pipes no " sweating " due to passage of water through the pores takes place under any conditions. For this reason also there is no fear with steel pipes of bacterial or other contamination of a pure water supply from the surrounding soil. By the use of bitumen on the lines indicated corrosion is prevented, the steel pipes being treated when hot, and also bituminous compositions and cloth wrappings being employed if required.

Again, steel is elastic, so that the whole pipe line can bend to an appreciable degree without difficulty quite apart from the flexibility given by the use of special joints and couplings of the non-rigid type. This elasticity is of great advantage in connection with subsidence, general earth movements, and vibration due to heavy motor traffic in large towns.

Finally, for the same duty, steel is much lighter in weight than cast iron or cement fabric, so that lengths up to 40 ft. can be handled by means of motor vehicles of the six-wheel or eight-wheel type, even in the roughest country without roads and almost impassable to any other type of transport, even with light loads.

The Analytic Quartz Lamp as a Rapid Means for Testing.

IT is generally recognised that the responsibility rests on the buyer of a commodity to ascertain that it is genuine. This applies to a wide range of commodities and products that are not readily tested by ordinary means. Many of these, however, can easily and instantaneously be tested with the analytic quartz lamp, which develops a powerful beam of ultra-violet rays. These rays have the peculiar property of causing many substances to fluoresce in striking colours. The colour in each instance is characteristic of the composition ; an imitation or substitute will not reproduce the same fluorescent colour. The results of the test must, of course, be taken in conjunction with other physical and chemical tests. The fluorescence test is not an absolute criterion of genuineness ; it does, however, provide an instantaneous visual, specific test of very wide application. It involves no " sampling " or injury to the specimen tested. In a few seconds it frequently gives a result that saves hours of elaborate and costly analysis.

The importance of fluorescence in scientific and technical work can best be gauged from the fact that since the introduction of the Hanovia analytic lamp only a few years ago, over 800 books and papers on the subject have been published by chemists and research workers. Kitching points out that with such an apparatus a means of detection is available which approaches the spectroscope in exactitude.

The action of radium, X-Rays, and ultra-violet rays on a large number of minerals has been investigated by Kunz and Baskerville. It was found that the reaction of a specimen to these three kinds of rays was so strongly characteristic that it could be used for the identification of the stone, and even for the determination of its origin. With minerals also, specimens of different origin show characteristic differences in fluorescence. The fluorescent effects are particularly brilliant in the Willemite group. Even in the case of fuel oils, Wittlich tested distillation products from Esthonian and Manchurian oil shales under the analytic quartz lamp. He found that the lamp could give useful indications regarding the origin, process, and cleaning of these substances, and with a little practice, even the individual fractions can be graded by their fluorescence, corresponding to their boiling points.

Catalogues and Other Publications

The products of some firms cover such a wide range that buyers are frequently in difficulties in determining the extent of this range. This difficulty is appreciated by Edgar Allen and Co., Ltd., Imperial Steel Works, Sheffield, 9., who have just issued an alphabetical guide to their products. It is arranged in a very simple manner and yet gives a classified list of the entire range of manufactures. Reference is easy, its use will simplify the work of the buyer and for this reason a copy should be obtained from Edgar Allen and Co., Ltd.

A new catalogue has just been published by Ruston and Hornsby, Ltd., of Lincoln, dealing with this firm's range of fuel-oil locomotives. The range has recently been revised, and now comprises three models—viz., 10 h.p., 16/20 h.p., and 22/28 h.p., the last named being a recent addition, equipped with a three-cylinder engine. In all three models a three-speed constant-mesh gearbox is fitted, a description of which is given in this publication together with much other information regarding these locomotives.

Personal.

The Carborundum Company Ltd., Trafford Park, Manchester, have appointed Mr. E. A. Cartwright to represent them in Lancashire, Cheshire and North Wales for Carborundum and Aloxite Brand Grinding Wheels. Mr. Cartwright has been connected with The Carborundum Company Ltd. for over twelve years, and has a wide knowledge of the grinding requirements of the firms in this territory.

Canadian Institute of Mining and Metallurgy

ANNUAL MEETING AT QUEBEC

THE annual convention of the mining men of Canada, always a notable event, has taken on added importance during the last few years, since the relative importance of mining as a source of revenue to the Dominion is recognised more than ever before. At the invitation of Hon. J. E. Perrault the meeting was held in Quebec, at the Chateau Frontenac, on April 3-5. The meeting brought together leaders of the mineral industry in Canada and representatives from abroad. At the conclusion of the initial business meeting, Mr. Selwyn G. Blaylock, general manager and vice-president of Consolidated Mining and Smelting Company, was installed as President.

The presentation of papers, which formed an important part of the programme of this meeting, covered a wide variety of interests. The copper-gold deposits of Noranda, the Beattie gold mine, and the new mining method at the King asbestos mine at Thetford represented the industry in Quebec. The Falconbridge nickel smelter and the Vipond gold mine are Ontario properties that were described. The Flin Flon mine, smelter and refinery was considered in a symposium that recorded suitably the establishment of this gold-silver-copper-zinc producer in the far north of Manitoba. Features of the huge smelter at Trail and a study of the British Columbia goldfields represented this province's interests.

A feature that attracted much public attention was a discussion by Mr. W. Amyot of " The Fraud Prevention Act of Quebec," which he administers, and of " The Ontario Securities Act," by W. E. Segsworth. The good and bad points of these acts were brought out plainly, so far as they affect the mining industry. A paper on " Taxation of a Canadian Gold Mining Company," by Mr. E. D. Fox, gave rise to a good deal of animated discussion.

A feature of the meeting was the attendance of some of the Dominion's most notable prospectors, who held a special session presided over by Mr. Robert J. Jowsey, who described God's Lake, the latest of his numerous finds. Gilbert Labine told how he found the radium and silver ores at Great Bear Lake ; F. M. Wells described placer gold mining in the famous old Cariboo camp ; while Ed. Horne, of Noranda, John S. Wilson, of Dome, Russel Cyderman, of Sudbury, Jay Kenty, and others equally well known told about discoveries with which their names are associated.

Among the Institute's members who took part in the proceedings were Dr. W. H. Collins, Director of Geological Survey ; J. F. Murdoch, of Toronto ; J. G. Ross, of Thetford Mines ; R. E. Phelan, of Flin Flon ; R. W. Diamond, of Trail ; J. K. Snelgrove, of Newfoundland ; and a number of others equally representative of the widespread and varied mining interests of the Dominion and its island neighbour.

Presentation of Awards.

Not the least interesting feature of this meeting was the presentation of awards, probably the most outstanding being the presentation of the Inco Medal to Robert E. Phelan for a meritorious and practical contribution of great importance to the mining and metallurgical industry in Canada. This award was established last year by the International Nickel Company of Canada to mark the fiftieth anniversary of nickel ore at Sudbury. The contribution to mining and metallurgy that gained for Mr. Phelan this distinction refers to his work in connection with the development of the Flin Flon ore in Manitoba. Discovered in 1915 at a distance of 90 miles from the railway, huge in size but low in grade and complex in its nature, the ore deposit remained unused for ten years. Scores of engineers examined it and a number of substantial mining companies attempted to find a means of exploiting it, but it remained a tantalising possibility. In 1925, however, Mr. R. E. Phelan examined the deposit, formulated a plan for working it and struck a bargain with the owners. Then there began a course of development which, for speed and thoroughness in a remote locality, is without parallel in Canada and possibly throughout the world.

Mr. Phelan's first task was to check the tonnage and grade of the Flin Flon ore, to find a method of separating out the gold, silver, copper, and zinc it contained, and to locate a water supply near that would provide the requisite cheap power. By the summer of 1926 these three points had been sufficiently determined to warrant the erection of a 25-ton pilot mill on the property. This worked so well that by the end of 1927 it was decided to complete the purchase of the property, install a plant of 3,000 tons daily capacity, and build a 44,000 h.p. power plant. In June, 1930, power from Island Falls was available at the mine, and in November continuous operations were under way in the various plants. The mine had been developed, the mill, smelter, and zinc refinery constructed, and the power plant put into operation in less than two years. And the results from the full-sized plant were better than those obtained from the pilot mill—a larger proportion of the gold, silver, copper, and zinc were being saved. This bold undertaking, without precedent, was rendered possible by the organising capacity of Mr. Phelan, and the enthusiasm with which he inspired his staff.

Another interesting ceremony at the initial meeting was the award of the Leonard Medal to Mr. C. H. Hitchcock, the chief technical officer and a partner in the firm of Smith & Travers & Co., Ltd., of Sudbury. Established by the late Lt.-Col. R. W. Leonard as an annual award for the best paper on mining presented, Mr. Hitchcock secured the medal for his comprehensive paper on " Diamond Drilling Practice," which he presented before the annual meeting of the Canadian Institute of Mining and Metallurgy.

A few years ago the Canadian output of sulphuric acid, the most important of the heavy chemicals, was made mainly from imported sulphur. To-day, by far the larger part of the sulphuric acid used in Canada is made from waste smelter gases. This change has been brought about largely through the initiative and skill of Mr. William H. De Blois, of Montreal, who has had a life-long experience in the manufacture of this important chemical. In recognition of his latest achievement in making sulphuric acid from the smelter gases at Sudbury, Mr. De Blois has been awarded the Randolph Bruce Gold Medal for 1933.

All the world knows that the science of geology contributes largely to the progress of the mineral industry, and none realise this fact more than the mining engineers who conduct the industry. Thus, in memory of an eminent geologist, Dr. Alfred E. Barlow, President of the Institute during 1912-13, who was drowned in the *Empress of Ireland* disaster, the Barlow Memorial Prize was founded. It is awarded annually for the best paper of the year on economic or applied geology. This prize was awarded to Mr. L. Telfer, of Consolidated Mining and Smelting Company, for his paper entitled " Phosphate in the Canadian Rockies."

Business Notes and News

New Armour-piercing Projectile.

Some remarkable illustrations of the power of the big gun that is equipped with armour-piercing projectiles, as compared with guns of smaller calibre, were given by Sir Robert Hadfield at the annual meeting of Hadfields, Ltd., recently, which should be borne in mind when considering the building of warships of smaller tonnage. He referred to results obtained with the latest Hadfield-Clerke armour-piercing projectile, which is claimed to be the world's most efficient shell. Weighing nearly one ton a shell of this class was fired at a modern hard-faced armour plate having a thickness about equal to the calibre of the gun. An energy of the order of 45,000 to 50,000 foot-tons was developed. Not only did the shell perforate the plate and emerge unbroken, but it possessed a remaining velocity sufficient to carry it a further nine miles. When fired against a hard-faced armour-plate that was inclined 30 degrees a shell of this class perforated the plate unbroken, and retained sufficient energy to carry it a further 11 miles. Both these projectiles, said Sir Robert, with very little touching up in the lathe or grinding machine, could have been put in the gun and fired again.

Translated into terms of fighting ranges, the efficiency of this new projectile would mean that whereas a shell of ordinary construction would cease to be efficient at ranges over, say, 12,000 yds., the efficiency of this shell, with relieved base, was extended to, say, 15,000 yds., so that a ship equipped with this new type of shell could, by a choice of fighting range, effectively destroy an enemy ship equipped with the ordinary type of shell, without herself suffering appreciable damage.

Nickel Coinage.

Messrs. Henry Wiggin & Co., Ltd., have received a further order for 5 million pure nickel coin blanks for Abyssinia, bringing the quantity of blanks ordered by this Government in the last eighteen months to over 100 tons.

Obverse and reverse sides of pure nickel Abyssinian coins.

The new nickel coins are being struck at Addis Ababa and two denominations, equivalent to ¼ and ½ Talari, have already been issued. The obverse side of the coins shows the head of the Emperor Haeli Sellasie and the reverse the Lion of Judah.

It is interesting to note that the addition of Abyssinia brings the number of countries which have issued pure nickel coinages up to 28.

New Department at Wolseleys.

A new department, known in the works as the "Swarf Shop," has been opened at the Wolseley factory. As is well known, the swarf comprises the shavings or chippings of metal resulting from the transformation of rough castings or forgings into finished parts by machine-tool operation. The material, which collects in quantities under the machines, is always heavily coated with the oil used for drenching the tools during cutting, of which a large amount is used daily.

Under the new system, swarf, as soon as it is formed, is transferred to the Swarf Shop, where it is spun at high speed in large circular containers. The oil with which it is covered is flung off by centrifugal force, running down into tanks to be purified and re-issued for use. The cleaned swarf is then tipped into trucks on the company's private siding for delivery to scrap-metal merchants.

In the first few days of working over 600 gallons of oil per day were reclaimed, and it is estimated that eventually over 90% of the oil used in the Wolseley machine shops, the largest of their kind in Europe, will be saved. Previously this vast quantity of lubricant was wasted, and, in addition, the oily swarf was of less value to the metal merchants than the cleaned material.

Blaenavon Hematite Pig Iron

An event of considerable importance to ironfounders is the restarting of Blaenavon blast furnaces. The hematite pig iron produced from these furnaces has always enjoyed a high reputation for quality, perhaps because no effort has been made to drive the plant for record outputs. We understand the same standard will be maintained by using high-grade ores and smelting with selected coke from the company's own ovens. Messrs Bradley & Foster, Ltd., Darleston, are acting as distributing agents for the Blaenavon Company, Ltd., and welcome enquiries for delivery for April and onwards. At the moment favourable prices are being quoted for forward delivery, which, apart from the question of quality, make Blaenavon iron an attractive proposition.

Bessemer Gold Medal, 1934.

The Council of the Iron and Steel Institute announce that His Majesty the King has been graciously pleased to accept the Bessemer Gold Medal of the Institute for 1934. His Majesty the King has been the Patron of the Iron and Steel Institute since his accession.

The Bessemer Gold Medal was founded in 1873 by the late Sir (then Mr.) Henry Bessemer, the discoverer of the Bessemer process of steel-making, and the second President of the Iron and Steel Institute. It has been awarded annually since that date to distinguished benefactors of the industry and particularly for pre-eminent contributions towards the scientific and technical knowledge of iron and steel. In 1899 Queen Victoria, and in 1906 King Edward VII. agreed to be recipients of this medal.

Aluminium Foil as an Insulator.

The insulting properties of aluminium foil were demonstrated recently by Dr. G. P. Crowden, of the Department of Industrial Physiology of the London School of Hygiene and Tropical Medicine. Experimenting with police helmets, he found that the temperature inside the hat with aluminium foil lining was 109° with a man perspiring, under similar conditions but using a helmet with ordinary lining the temperature rose to 120°. Dr. Crowden stated that on a liner in a cabin near the funnel, in which the temperature rose to 120°, he had brought it down to 87° by inserting a sheet of foil. Experiments have shown that petrol tanks in Egypt lost through heat about 70 gals. of spirit per week ; by insulating the tanks with this foil, however, there was practically no loss at all. It is claimed that the insulating properties of a layer of this foil are equal to 13 in. of brick, yet in appearance it is like chocolate or cigarette foil. The statement was made that a firm in London has decided to manufacture the material.

Boring for Oil.

Renewed interest in British oil production is being taken as a result of the Government's announcement of a Bill to give the State control over the production of oil found in Great Britain. This action has been taken as a result of inquiries recently made by foreign oil interests into the possibilities of obtaining oil in commercial quantities in the Midlands.

Boring is being expedited at Worth, near Crawley, Sussex, where oil has been found. A well has been bored to a depth of 1,876 ft. and oil has been struck, but not in commercial quantities. It is hoped to reach the Portland oil sands, at a depth of 1,970 feet, during the next few weeks, and it is expected that oil will be found in commercial quantities. Boring is also proceeding in Derbyshire and satisfactory results are expected shortly.


Imperial Airways have placed an order with the De Havilland Aircraft Company for a fleet of express air liners of the D.H. 86 type for use this summer between London and the Continent, and on the inland air lines to be operated by Railway Air Services, Ltd. The D.H. 86 is a four-engined machined with a top speed of 170 miles per hour, and is stated to be the fastest four-engined passenger aeroplane in the world. By the use of these machines the air journey between London and Paris will be reduced by three-quarters of an hour. Railway Air Services have not decided what services they will run, but it is anticipated that they will concentrate on a main north-south service between London and Scotland, via Manchester or Liverpool, extending to Belfast.

Some Recent Inventions.

Separating Sheets after Pack Rolling

In the manufacture of black plates the usual practice is to roll two steel bars and the thick sheets resulting are superimposed and again rolled, doubled, rolled and doubled again and finally rolled to present a set of eight sheets connected along certain of their edges. Such sheets are usually known as " eights." With variations of the folding of the sheets, groups of twelve or sixteen or other number of sheets may be formed. The rolling is effected
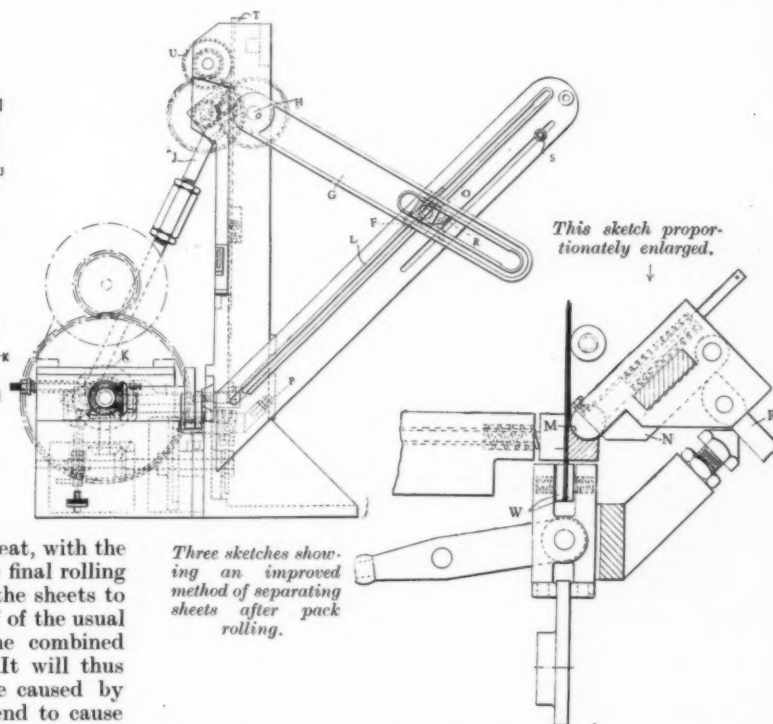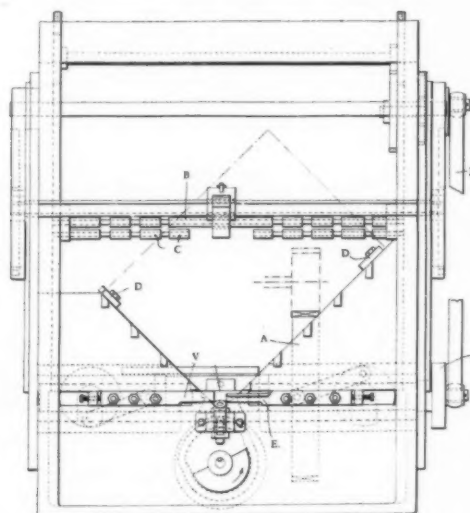
while the bars and sheets are at a bright-red heat, with the result that adjacent sheets adhere. After the final rolling the edges of the eight are sheared off to cut the sheets to the correct dimensions. The finished sheets, if of the usual thickness, are about .012 in. thick, so that the combined thickness of an eight will be about ⅒ in. It will thus be appreciated that apart from the adherence caused by the rolling of the sheets, the shearing will tend to cause the edges to adhere by burring.

The practice has been to separate these sheets manually, with the result that considerable waste has been customary, usually about 12·5% depending upon the skill of the operator, but it is found that some of the sheets adhere so firmly that separation is impossible without damage. An improved method of separating the sheets, however, has recently been developed which is claimed to reduce wastage and to effect separation in an expeditious manner. By this method a pack of sheets X to be separated is inserted through a recess in a machine frame, and mounted cornerwise in a trough A and prevented from falling forward by rollers B, C, and backwards by stops D, D. The bottom of the trough is cut away to allow the corner of the pack to project below, in the path of a reciprocated knife E which gets between the corner .of the top sheet and bends out the corner from the pack. A hammer F mounted on lever arms G swinging downwards about the shaft H by the connecting-rod J of a crank disc K, slides down the groove L, and strikes the bent corner to bend it into the recess M of the knife E, so that the sheet corner can be gripped by finger grippers N which move down on the slide block O along with the hammer. A stop P pivots the cam-lever R which urges the gripper jaws N to close on the corner of the sheet and hold it. The arms G are then swung up, so that the grippers N tear the sheet up away from the rest of the pack. On arriving at another

stop S the lever R fouls it which separates the gripper fingers N, and drops the sheet. As the sheet is stripped off the pack the pack support rollers B, C move up by rack and pinion T, U to allow stripping. The pack is moved up to the path of the knife by a pressure-plate connected by spring pressure to a cam-actuated slide. The faces of the sheets which are burred by the previous shearing come in contact with the surface of the abutment V which exercises a planishing effect on the edges. The abutment V is moved up by a crank, but is timed to recede as the knife advances. As soon as the corner is bent out the scissors gripper W is raised up by cams to grip the corner of the remaining pack and hold it during stripping of one sheet, as previously described. The pack is forced by spring pressure against the abutment V, and the knife is adjusted to engage the top sheet. When the sheet is being stripped off it is pulled from between the roller B

This sketch proportionately enlarged.

Three sketches showing an improved method of separating sheets after pack rolling.

and C which travel vertically up the framework over the face of the pack during stripping. The abutment V may be replaced by a second reciprocating knife.

404,049. J. A. GENGE, West Cross, Swansea, and D. GEORGE, Glanmor, Swansea. January 11, 1934.

Casting Liners in Bearings.

A METHOD has been devised for coating a bearing surface with molten metal having a higher coefficient of expansion, in which the coating is extended before it has become so cold that the process induces hardening. The metal surface to be coated is first treated with solder by spraying or dipping, then the second metal is cast on, and, finally, the solidified metal is pressed continuously or intermittently to expand it in the direction of the joint while still hot. In lining a 2½-in. steel bearing shell this may be coated with an alloy of zinc and cadmium in equal parts, using a flux of zinc chloride, heated to 250-400° C., rotated at 700 r.p.m., and cadmium, containing 1% each of copper and magnesium cast in. The speed is increased to at least 3,000 r.p.m., and continued until the temperature has fallen to 100° C., or the cast metal may be worked by fluid pressure, or by rolling or other tools.

398,808 and 398,809. STONE & CO., LTD., Deptford, London, A. J. MURPHY, Teddington, Middlesex, and W. ROSENHAIN.

Wire-drawing Dies.

THE method adopted in the manufacture of cemented carbide dies occupies much time and must be carried out by experienced operators having special skill, because the dimensions and contour of the opening through the die must be minutely accurate. Further, it is not unusual to wear out several forming tools in providing the proper shaped opening through each die, the forming tools being usually made of relatively soft material, such as iron. An
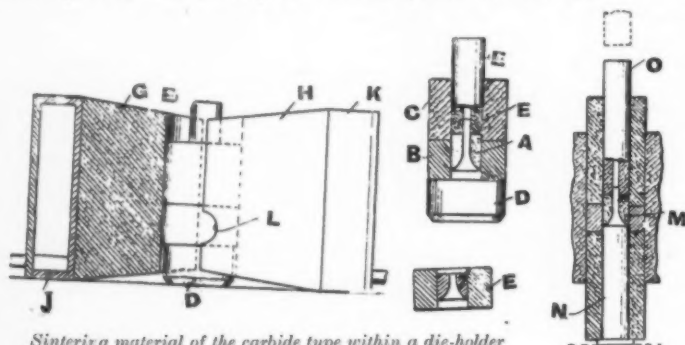
*Sintering material of the carbide type within a die-holder
for wire drawing.*

improved method has been developed, however, the object of which is to provide a simple, cheap, and efficient process for manufacturing wire dies from powdered materials, and particularly from powdered materials consisting of a refractory carbide and a binder metal.

The improvement consists in sintering material of the cemented refractory carbide type within a die holder and around a central core corresponding in contour to the interior of the required die-nib. In this method of wire-drawing die manufacture, the die comprises a die-holder of suitable material and a cemented carbide die-nib securely welded to it. The method, shown in the accompanying illustrations, consists in placing the sintering powdered material A in a mould, which comprises a die-holder B and a graphite cylinder C, and is pressed around the stem of a graphite core D by a plunger E made of carbon, tungsten, molybdenum, or a refractory such as quartz, alumina, magnesia, etc. The stem F may be made of quartz, may have any desired cross-section, and may extend through the core. The assembled mould and charge is heated between two carbon blocks G, H by electricity supplied from water-cooled terminals J, K. Openings L in the blocks allow the temperature of the die-holder to be ascertained. The die, comprising the assembled nib, is shown in sketch. The die-holder may also be made from powdered material, preferably molybdenum, or an alloy thereof, by pressing between plungers in a split graphite mould and sintering by electricity. A nib is attached by placing in the holder powdered material M, and a core N, as before, and transferring the assembled parts with a plunger O into the split mould for sintering. The nib may be made from refractory carbides, and binding metals of the iron group with or without metals such as tungsten, molybdenum, chromium, or aluminium.

398,717. THE BRITISH THOMSON-HOUSTON CO., LTD., Crown House, Aldwych, London, W.C., assignees of of Geo. F. Taylor. September 21, 1933.
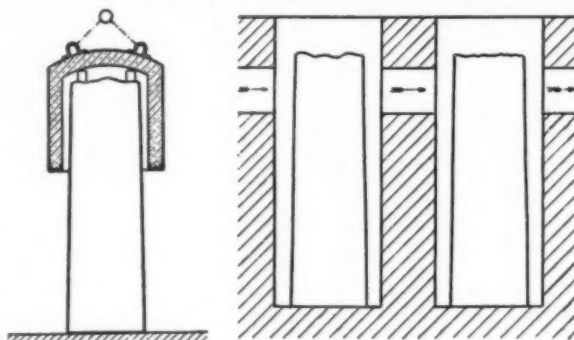
Improving the Quality of Steel Ingots.

IT is customary to reduce the loss of heat from the upper end of an ingot of " rimmed " steel by the use of a covering mounted on the ingot mould. The use and action of this protective covering ceases, however, at the moment when the covering is removed in order to strip the mould from the ingot so that the latter can be placed in the soaking pit. When this is effected the metal at the centre of the ingot is still in a molten condition, and the separation of the slag is not complete, consequently the favourable effect which is obtained from the use of a protective covering is

only satisfactory if during the period between the separation of the mould and the complete solidification of the ingot such conditions obtain as will enable the deoxidised slag, which separates out as the temperature in the molten centre of the ingot drops, to rise until it is finally within reach of the normal scrap iron end.

The object of a recent improved method is to effect complete solidification of the lower part of the ingot before the upper part. Under normal working conditions under which ingots of rimmed steel solidify, solidification of the ingot proceeds in the reverse order or the last of the metal to solidify is at about the centre of the ingot. This improved method is designed to retard the solidification of the centre of the head and to accelerate that of the lower part of the ingot. For this purpose a heat protective hood is placed over an ingot or number of ingots immediately after separation from the mould, the hood being so arranged that it does not cover the lower part of the ingot, as in Fig. 1. This method is applicable when it is not possible to transfer the ingot to the soaking pit immediately. If, however, the ingot can be accommodated in the soaking pit immediately after stripping arrangements are made for heating the upper ends ; one of a number of methods for effecting this operation being shown in Fig. 2. After the ingots have become completely solidified by this method, further treatment is necessary to raise the ingots to a uniform temperature suitable for rolling.

It is claimed that the method can also be employed for ingots which are to be cast " killed," though it will be appreciated that the operations involved in solidifying differ very considerably with the two kinds of steel. With rimmed steel the method is directed to a more complete

Fig. 1.   *Fig. 2.*
Improving the quality of steel ingots.

separation of the deoxidation slag ; in the case of killed steel, the end aimed at is the reduction in length of the fissure, and, according to the results of experiments, this method reduces the length of the fissure very considerably.

398,740. VEREINIGTE STAHLWERKE AKTIENGESELL-SCHAFT, Dusseldorf, Germany. September 21, 1933.

Forthcoming Meetings

THE INSTITUTE OF METALS.

A general meeting will be held at the Institution of Mechanical Engineers on Wednesday, May 9, at 8 p.m., when the Twenty-fourth Annual May Lecture will be delivered by Professor E. K. Rideal, F.R.S., on " Gases and Metal Surfaces."

THE INSTITUTION OF MECHANICAL ENGINEERS.

A general meeting will be held on Friday, April 20, at 6 p.m., at which a paper will be presented by F. M. Birks, O.B.E., M.I.Mech.E., on " Gas Furnace Practice."

An informal meeting will be held on Friday, May 4, at 7 p.m., when R. C. Walker, B.Sc., will deliver a lecture on " Photo-Electric Cells and their Application."

MARKET PRICES

ALUMINIUM.

98/99% Purity	£100	0	0

ANTIMONY.

English	£39 10 0 to £40	0	0
Chinese	33	0	0
Crude	21	0	0

BRASS.

Solid Drawn Tubes	lb.	9d.
Brazed Tubes	,,	11d.
Rods Drawn	,,	8¾d.
Wire	,,	7¾d.
*Extruded Brass Bars	,,	4¼d.

COPPER.

Standard Cash	£33	8	0
Electrolytic	37	0	0
Best Selected	35 10	0	
Tough	35	0	0
Sheets	62	0	0
Wire Bars	36 17	0	
Ingot Bars	36 17	0	
Solid Drawn Tubes	lb.	10d.	
Brazed Tubes	,,	10d.	

FERRO ALLOYS.

‡Tungsten Metal Powder	lb.	0	3	0
‡Ferro Tungsten	,,	0	2	9
Ferro Chrome, 60-70% Chr. Basis 60% Chr. 2-ton lots or up.				
2-4% Carbon, scale 11/- per unit	ton	33	2	6
4-6% Carbon, scale 7/- per unit	,,	23	0	0
6-8% Carbon, scale 7/- per unit	,,	22 10		0
8-10% Carbon, scale 7/- per unit	,,	22 10		0

§Ferro Chrome, Specially Refined, broken in small pieces for Crucible Steel-work. Quantities of 1 ton or over. Basis 60% Ch.

Guar. max. 2% Carbon, scale 11/0 per unit	,,	34	5	0
Guar. max. 1% Carbon, scale 12/6 per unit	,,	36 10		0
§Guar. max. 0·7% Carbon, scale 15/- per unit	,,	39	2	6
‡Manganese Metal 97-98% Mn.	lb.	0	1	4
‡Metallic Chromium	,,	0	2	5
§Ferro-Vanadium 25-50%	,,	0 12		8
§Spiegel, 18-20%	ton	7 10		0
Ferro Silicon—				
Basis 10%, scale 3/- per unit	ton	6	5	0
20/30% basis 25%, scale 3/6 per unit	,,	8	2	6
45/50% basis 45%, scale 5/- per unit	,,	11 17		6
70/80% basis 75%, scale 7/- per unit	,,	18 10		0
90/95% basis 90%, scale 10/- per unit	,,	30	0	0
Silico Manganese 65/75% Mn., basis 65% Mn.	,,	13 15		0
§Ferro - Carbon Titanium, 15/18% Ti	lb.	0	0	4½
Ferro Phosphorus, 20-25%	ton	15 18		0
§Ferro-Molybdenum, Molyte	lb.	0	5	6
§Calcium Molybdate	,,	0	5	4

(NOMINAL — bracketing the Ferro Chrome 2-4% to 8-10% Carbon rows)

FUELS.

Foundry Coke—					
S. Wales	1	5	0 to	1 10	0
Scotland		—		1	8	0
Durham	1	1	0 to	1	5	0
Furnace Coke—					
Scotland		—		1	5	0
S. Wales	0 19	0 to	1	0	0
Durham				0 17	6

GUN METAL.

*Admiralty Gunmetal Ingots (88 : 10 : 2)	£54 15		0
*Commercial Ingots	42	0	0
*Gunmetal Bars, Tank brand, 1 in. dia. and upwards .. lb.	0	0	9
*Cored Bars	,,	0	0	11

LEAD.

Soft Foreign	£11 11		0
English	13	0	0

MANUFACTURED IRON.

Scotland—			
Crown Bars, Best	£10	5	0
N.E. Coast—			
Rivets	10 15		0
Best Bars	10	5	0
Common Bars	9	5	0
Lancashire—			
Crown Bars	9	0	0
Hoops	£10 10 0 to	12	0	0
Midlands—			
Crown Bars	9 12		6
Marked Bars	12	0	0
Unmarked Bars ... from	7	5	0
Nut and Bolt Bars	£6 15 0 to	7 10		0
Gas Strip	10 12		6
S. Yorks—			
Best Bars	10 15		0
Hoops	£10 10 0 to	12	0	0

PHOSPHOR BRONZE.

*Bars, "Tank" brand, 1 in. dia. and upwards—Solid	lb.	9d.
*Cored Bars	,,	11d.
†Strip	,,	10½d.
†Sheet to 10 W.G.	,,	11d.
†Wire	,,	12d.
†Rods	,,	11d.
†Tubes	,,	1/4
†Castings	,,	1/1½

†10% Phos. Cop. £30 above B.S.
†15% Phos. Cop. £35 above B.S.
†Phos. Tin (5%) £30 above English Ingots.

PIG IRON.

Scotland—			
Hematite M/Nos.	£3 11		0
Foundry No. 1	3 12		6
,, No. 3	3 10		0
N.E. Coast—			
Hematite No. 1	3	8	0
Foundry No. 1	3 10		0
,, No. 3	3	7	6
,, No. 4	3	6	6
Silicon Iron	3 10		0
Forge	3	6	6
Midlands—			
N. Staffs Forge No. 4	3	7	0
,, Foundry No. 3	3 11		0
Northants—			
Foundry No. 1	3 10		6
Forge No. 4	3	2	6
Foundry No. 3	3	7	6
Derbyshire Forge	3	6	0
,, Foundry No. 1	3 14		0
,, Foundry No. 3	3 11		0
West Coast Hematite	3	7	0
East ,,	3	8	0

SWEDISH CHARCOAL IRON AND STEEL.

Kr. per English ton @ 18-16 to £1 approximately.
Pig Iron Kr. 98
Billets Kr. 230-290 £12 13 4-£16 0 0
Wire Rods Kr. 265-320 £14 12 6-£17 12 6
Rolled Bars (dead soft)
Kr. 185-210 £10 4 0-£11 11 0
Rolled Charcoal Iron Bars
Kr. 290 16 0 0
All per English ton, f.o.b. Gothenburg.

SCRAP METAL.

Copper Clean	£28	0	0
,, Braziery	25	0	0
,, Wire		—	
Brass	20	0	0
Gun Metal	26	0	0
Zinc	9 10		0
Aluminium Cuttings	70	0	0
Lead	10 10		0
Heavy Steel—			
S. Wales	2 12		6
Scotland	2 11		6
Cleveland	2	7	6
Cast Iron—			
Midlands	2	7	6
S. Wales	2	7	0
Cleveland	2 12		6
Steel Turnings—			
Cleveland	1 17		6
Midlands	1 12		0
Cast Iron Borings—			
Cleveland	1	7	6
Scotland	2	0	0

SPELTER.

G.O.B. Official		—	
Hard	£12 10		0
English	15 10		0
India	14 10		0
Re-melted	15	0	0

STEEL.

Ship, Bridge, and Tank Plates			
Scotland	£8 15		0
North-East Coast	8 15		0
Midlands	8 17		6
Boiler Plates (Land), Scotland	9	0	0
,, ,, (Marine) ,,		—	
,, ,, (Land), N.E. Coast	10	0	0
,, ,, (Marine) ,,	10 10		0
Angles, Scotland	8	7	6
,, North-East Coast	8	7	6
,, Midlands	8	7	6
Joists	8 15		0
Heavy Rails	8 10		0
Fishplates	12	0	0
Light Rails	£8 10 0 to	8 15		0
Sheffield—			
Siemens Acid Billets	9	2	6
Hard Basic ...£8 2 6 and	8 12		6
Medium Basic ..£6 12 6 and	7	2	6
Soft Basic	6	0	0
Hoops	£9 10 0 to	9 15		0
Manchester			
Hoops	£9 0 0 to 10	0	0
Scotland, Sheets 24 B.G.	10	5	0

HIGH SPEED TOOL STEEL.

Finished Bars 14% Tungsten	lb.	2/-
Finished Bars 18% Tungsten	,,	2/9
Extras		
Round and Squares, ¼ in. to ½ in.	,,	3d.
Under ¼ in. to 3/16 in.	,,	1/-
Round and Squares 3 in.	,,	4d.
Flats under 1 in. × ½ in.	,,	3d.
,, ,, ½ in. × ¼ in.	,,	1/-

TIN.

Standard Cash	£239	0	0
English	239 10		0
Australian	240 17		6
Eastern	241	5	0
Tin Plates I.C. 20 × 14 box	0 16		6

ZINC.

English Sheets	£24	0	0
Rods	29	0	0
Battery Plates		—	
Boiler Plates		—	